

Missouri Department
of Transportation

Research
Development
and Technology



Annual Report
FY 2003

RESEARCH, DEVELOPMENT, AND TECHNOLOGY ANNUAL REPORT 2003

To our Research, Development and Technology Transfer Customers:

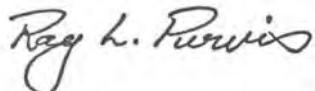
“The recipe for perpetual ignorance is to be satisfied with your opinions and content with your knowledge.” I can’t attribute this quote but find this statement to be a strong motivator for our research, development and technology transfer efforts at MoDOT. We all know that we can’t rely on our opinions or on our existing knowledge if we want to maintain a viable transportation system.

The strategic priorities for the Missouri Department of Transportation (MoDOT) are to **maintain the system we have, finish what we have started, and to build public trust**. RDT plays a major role in supporting these priorities in the diversity of research, development and technology transfer projects and tasks that we have taken on in recent years. RDT’s goals in support of the MoDOT strategies requires us to **increase our policy research, strengthen our implementation efforts and expand our communication and customer base while working towards quick and efficient solutions or new technology for our transportation system**.

When we have the knowledge, abilities and resources available internally, RDT will complete the research, development and technology transfer. When we do not have these resources available we will look to our University and industry partners for contract research.

The selected projects featured in this summary are samples of the various projects studied by RDT, and as you will see, the past year has been very diverse as well as productive. As researchers, the year ahead will continue to offer us challenges to expand the knowledge base for MoDOT and our transportation industry.

Respectfully,



Ray L. Purvis, P.E.
State Research, Development and Technology Engineer

Contents

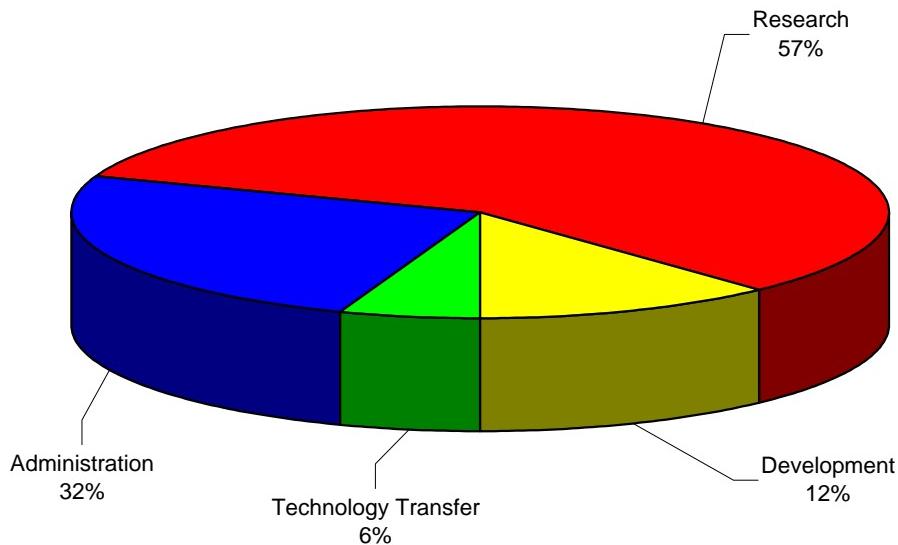
PAGE 1	FINANCIAL SUMMARY
PAGE 3	POOLED FUND STUDIES
PAGE 11	PROJECT DEVELOPMENT / BRIDGE
PAGE 21	GEOTECHNICAL
PAGE 27	OPERATIONS
PAGE 33	PAVEMENTS
PAGE 41	SAFETY / TRAFFIC
PAGE 47	SOCIAL / ECONOMIC / ENVIRONMENTAL
PAGE 55	TECHNOLOGY TRANSFER
PAGE 63	TASK AND ACTIVITIES JUNE 2002 - JULY 2003
PAGE 67	FINAL PUBLICATIONS JUNE 2002 - JULY 2003
PAGE 69	RESEARCH IDEA STATEMENT FORM
PAGE 71	PRODUCT LISTING / NEW PRODUCT EVALUA- TION REQUEST FORM
PAGE 73	IMPLEMENTATION FORM

Financial Summary

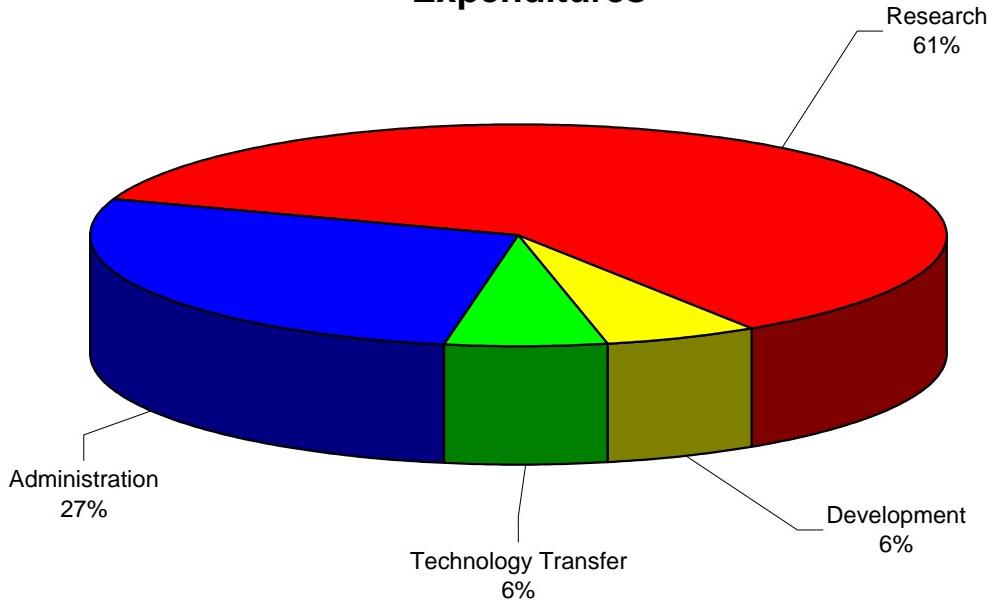
FY 2003

	Budget Amount	Expenditures
Administration	\$1,136,057	\$1,052,771
Research	2,612,252	2,326,954
Development	540,605	217,920
Technology Transfer	252,507	235,546
Total	\$4,541,421	\$3,833,191

Budget



Expenditures



Pooled Fund Studies

- Advanced Research of an Image Analysis System for Hardened Concrete
- Wind Induced Vibration in Cable Stay Bridges
- Intellizone - Freeway Work Zone Speed Advisory System
- Advanced Bridge Deck Inspection Technology (HERMES II)
- Cooperative Vehicle Highway Automation System (CVHAS)
- Long Term Maintenance of Load Resistance Factor Design (LRFD) Specifications
- Transportation Asset Management Research Program
- Design of Bridges for Security
- Material and Construction Optimization for Prevention of Premature Distress in PCCP

About the Transportation Pooled Fund Program

A pooled fund study may be initiated when there is widespread interest in a project that looks into solving a transportation related problem. Pooled fund studies are often jointly funded by federal, state, regional, and local transportation agencies, academic institutions, foundations, or private industries. One state, or agency, will act as lead on the project. The organization acting as lead agency is responsible for coordinating administrative activities, convening a technical advisory committee, publishing and distributing study reports, and various other duties. Partners in the pooled fund study commit funds and other resources to the project as requested.

RI 98-006 Advanced Research of an Image Analysis System for Hardened Concrete TPF-5(014)

Purpose: MoDOT routinely analyzes hardened concrete, in accordance with ASTM C-457, to determine its air content and air void structure for research and evaluation purposes. The air content and characteristics of the air void system are known to be an indication of a concrete's resistance in freezing and thawing conditions. The current means of analyzing hardened concrete is a manual operation, which is tedious, time-consuming, and requires a skilled and experienced operator. The effort of this study is to automate the operation using image analysis techniques.

Savings / Benefits: Automating the system would save both time and labor for increased efficiency and would improve consistency and repeatability of the operation for improved accuracy. Development of a reliable and accurate system producing results comparable to the current ASTM C-457 test method would offer an efficient means of hardened concrete analysis for many in the field of concrete materials, construction, and research.

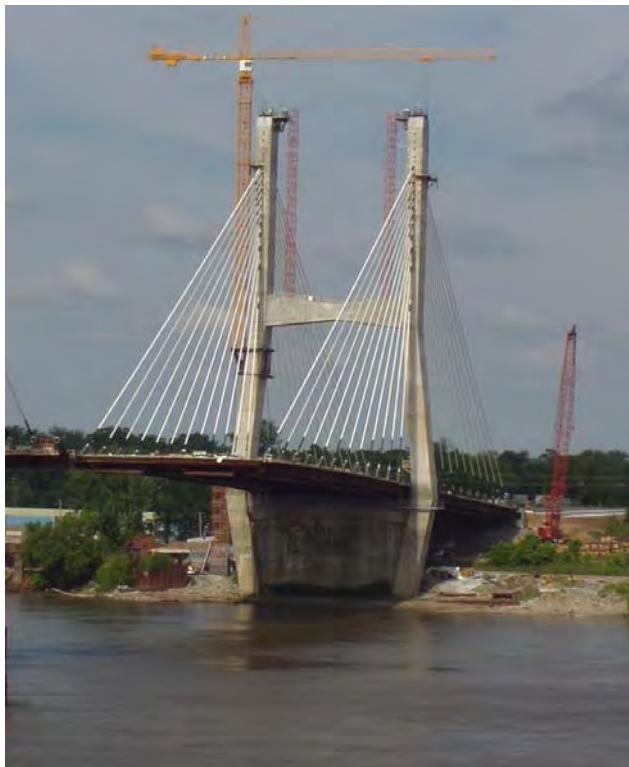
Status / Results: A cooperative effort between MoDOT and the U.S. Department of Energy, National Nuclear Security Administration-Kansas City Plant, has resulted in significant progress towards development of an automated image analysis system. MoDOT is currently serving as the lead agency in a pooled fund study effort involving ten other states to complete development of the system. A study completion date of 2004 is anticipated.

Implementation: At the completion of the study, it is anticipated that hardware specifications and software required for the automated system operation will be available for implementation by those in the concrete materials, construction, and research fields.



RI 98-034 Wind Induced Vibration in Cable Stay Bridges

Purpose: The purpose of the investigation was to develop guidelines for enhanced design for future structures and mitigation of vibration on existing structures created in cable stay bridges by the combined action of wind and rain. In late 1999, MoDOT agreed to be the lead state and participate in the \$800,000 national pooled funded project. Eleven other states and the FHWA agreed to participate. The study also included brief studies on live load induced vibrations and criteria to respond to the comfort levels of drivers and pedestrians. Missouri has three cable-stayed bridges which cross the Mississippi River and link with Illinois.



Savings / Benefits: Testing cable vibration will help show the effects of cable movement due to wind, live loads, etc. and also the effect that the dampening system has in reducing these reactions to prevent cable damage or failure. This will help prolong the life of the cables and lessen expenses associated with maintenance or replacement of cables.

Status / Results: Design guidelines were developed for the mitigation of vibrations based on wind tunnel tests and analytical and experimental research covering a range of linear and non-linear dampers and cross ties. The construction on one of Missouri's cable-stayed bridges, the Emerson Memorial Bridge in Cape Girardeau, is to be completed by the end of 2003. A cross tie dampening system is to be used on this bridge. Through this pooled fund study, testing will be done in Fall 2003 on the vibration in the stay cables and the effect of the cross ties before the bridge is opened.

RI 98-039 Intellizone - Freeway Work Zone Speed Advisory System

Purpose: The Quixote Intellizone system is a freeway work zone speed advisory system. The Intellizone system consists of three mobile count units per lane, mobile command unit and two variable message sign (VMS) units. The Intellizone project is part of the Midwest States Smart Work Zone Deployment Initiative, which studies improvements within work zones. The three mobile counter units measure the speed, density, and flow of the traveling public within the work zone. The mobile command unit will take information from the three mobile counter units on average speed, and send signals to the VMS units to indicate an appropriate message located approximately two miles and five miles upstream from the mobile counter units. The mobile command units communicate with the VMS units using line-of-sight or cellular communication. VMS units will provide a standard warning of the construction zone under free flow conditions. When traffic queues cause significant speed reductions, the VMS units will warn of the reduced speed ahead by displaying the downstream speed.

Savings / Benefits: While Intellizone provides no direct cost savings, it is anticipated that savings will be made through a reduction in property and time loss.

Status / Results: The Quixote Intellizone was implemented as a freeway work zone speed advisory system located on Eastbound I-70 near Wentzville, which is just west of St. Louis. The data was collected, and currently, University of Missouri-Columbia personnel are preparing a final report.

RI 99-016 Advanced Bridge Deck Inspection Technology (HERMES II)

Purpose: Ground Penetrating Radar (GPR) is a non-destructive method of testing various products of highway materials. It has been used by MoDOT to test concrete bridge decks and pavements for deterioration. MoDOT is a member with twenty other states in a pooled fund project called HERMES II. This is a multi-year project to develop a second generation High Speed Electromagnetic Roadway Measurement and Evaluation System, which could reconstruct a picture of a pavement or a bridge deck in three dimensions, much like a CAT scan, and acquire the data at highway speeds.

Savings / Benefits: MoDOT now does bridge deck surveys to determine costs of repairing deteriorated concrete. If this can be done by GPR at the same accuracy but at highway speeds, several savings could be realized. Costs of closing lanes of traffic and the safety of not having personnel exposed to traffic or motorists subject to congestion can be attained.



Status / Results: The first phase to come up with a better radar antenna was completed in 2001. Testing of the radar on field bridges and in the FHWA's Non-Destructive Evaluation labs at Turner Fairbanks was completed in 2003. The radar's resolution wasn't as good as hoped, and was not accurate enough to meet the pooled fund states goals for the project. An extension has been approved to allow additional testing and development in the Fall of 2003 before a decision to make a second prototype can be made.

RI 00-028 Cooperative Vehicle Highway Automation System (CVHAS)

Purpose: MoDOT is participating with 11 other state DOTs along with Honda Corporation Research and Development on this innovative research program. The purpose of this research is to refine and demonstrate CVHAS technologies with the ultimate goal of providing for the implementation of these technologies in Missouri's transportation system.

Savings / Benefits: Automation of many routine transit and transport operations will help to produce a more efficient transportation system. As automation becomes more common, society will see a savings in the cost of commercial transport, a reduction in congestion, and an improvement in safety.

Status / Results: Demo 2003, held by PATH and California DOT recently highlighted the progress of the project. Automated buses were used to demonstrate a potential implementation for mass transit. Using embedded magnetic nails for guidance and state of the art satellite radio communications between vehicles, participants rode in a bus platoon capable of increasing transit capacity and reducing roadway congestion. Similar technology is being developed for commercial vehicles for use to increase the efficiency of repeat trips between rail agencies, and between ports and freight transfer areas.



RI 02-031 Long Term Maintenance of Load Resistance Factor Design (LRFD) Specifications TPF-5(068)

Purpose: The objectives for this project are: (1) Resolve areas in LRFD documents requiring modification, clarification, or interpretation, (2) assist the technical committees of the bridge committee with special interpretations of LRFD documents, (3) prepare and submit recommended revisions for LRFD provided by the work of objectives 1 and 2, and (4) maintain a "Load and Resistance Factor Home Page" to ask questions and to present the on-going tasks of the project to the AASHTO committee and State DOT's.

Savings / Benefits: MoDOT will contribute to funding this 4-year project. MoDOT is planning on implementing LRFD design in 2005, so this project will be of great value in transitioning our bridge design methodologies.

Status / Results: A critical element in the future adoption and use of AASHTO LRFD methodologies by state departments of transportation is an awareness that the methodology and specifications will be maintained. The AASHTO Subcommittee on Bridges and Structures proposed a technical service program for the long term maintenance of LRFD specifications which will fund maintenance and development for four years starting in 2002. Iowa DOT agreed to act as the lead state for this effort and handle administrative duties for the project.

RI 02-035 Transportation Asset Management Research Program (Incorporating Road Safety Into Pavement Management) TPF-5(036)

Purpose: The purpose of the project is to determine the relationship between skid resistance and traffic safety. There are many factors that make up this relationship. Researchers will look at the asphalt pavement mix design, and develop a prediction model to predict skid resistance. The prediction model will take into account expected traffic, age of pavement, climate and pavement mix.

Savings / Benefits: The prediction model will be used as a tool to administer the department's asset management system and maintenance programs.

Status / Results: The pooled fund project is being lead by the Midwest Regional University Transportation Center. MoDOT is serving on the project advisory committee along with members from Georgia, Michigan, Ohio, Wisconsin and Wyoming. A study is scheduled to be complete by mid 2005.

RI 02-037 Design of Bridges for Security TPF-5(056)

Purpose: This is a pooled fund study initiated by the Texas Department of Transportation (Tx-DOT). Because bridge engineers have not needed to consider structural integrity in response to terrorist attacks, current guidelines do not consider the issue of bridge security. Information will be gathered and used to develop guidelines for the economic design of new bridges for security.

Savings / Benefits: The benefit will be a design for structures that will withstand terrorist attack with minimal damage to the bridge and will avoid loss of lives and long term loss of use of the structures.

Status / Results: The project is underway and is comprised of two phases. Phase I entails an international literature review and planning activities for carrying out Phase II. Phase II will result in comprehensive recommendations for transportation agencies.

RI 02-050 Material and Construction Optimization for Prevention of Premature Distress in PCCP TPF-5(066)

Purpose: This is a pooled fund study in which Iowa is the lead state. Project objectives include producing construction manuals to specify how to produce affordable, durable, and reliable concrete pavements by using mix optimization techniques. The construction manuals will include performance related test methods that could be used to measure performance of newly constructed concrete pavements. Also, computer software systems will be available to predict long-term performance of pavements, based upon material and construction inputs.

Savings / Benefits: MoDOT Research hopes to evaluate performance characteristics and new testing criteria of optimized PCCP mixes. If new testing procedures can be conducted to predict PCCP performance, then MoDOT could implement new performance related specifications in its concrete QC / QA program and possibly extend pavement design lives based upon better material characterization.

Status / Results: This project is only in its beginning phase. Completion date for this project is scheduled for 2008.

Project Development & Bridge

- High Performance Concrete for Bridge A6130, U.S. 412, Pemiscot County
- Laboratory and Field Testing of Fiber Reinforced Polymer Composite Bridge Decks & Laboratory and Field Testing of a Fiber Reinforced Polymer Concrete Bridge Deck
- Stainless Steel Reinforcing Bars in Bridge Decks
- Galvashield XP Embedded Galvanic Anodes to Inhibit Corrosion in Bridge Decks
- Implementation Issues of Metallic Dampers for Seismic Retrofit of Highway Bridges
- Laboratory Testing of PCC Bridge Deck Mixes
- Steel-Free Hybrid Reinforcement System for Concrete Bridge Decks: Phase I
- Strengthening Martin Springs Outer Road Bridge, Phelps County
- Post Earthquake Damage Evaluation of Bridge Structures
- Seismic Retrofit Techniques for Bridge Cap Beams, Columns, and Connections
- New Placing and Curing Specifications for Bridge Decks
- Preservation of Missouri Transportation Infrastructure: Validation of FRP Composite Technology Through Field Testing
- Predicting Chloride Ion Penetration of Hydraulic Cement Concrete by the Rapid Migration Test
- Statewide Study of Cathodic Protection Systems
- Cathodic Protection of Pier Caps Using Zinc Hydrogel Anode

RI 00-002 High Performance Concrete for Bridge A6130, U.S. 412, Pemiscot County (UMR)

Purpose: High performance concrete (HPC), identified as concrete with enhanced strength and durability characteristics, offers optimized designs and better performance for prestressed I girders and decks in bridge structures. This bridge project on Rte. 412 in Pemiscot County incorporates HPC in both the prestressed I girders and deck. Although this isn't the first project to apply HPC technology in Missouri, there is still a need to gather information regarding HPC concrete properties and evaluate the structural performance of bridges designed and built with HPC. Through a contract with the University of Missouri-Rolla (UMR), the Rte. 412 structure has been instrumented to monitor temperatures, strains, and deflections during the first two years following construction. HPC mix samples were also obtained during construction for laboratory testing of several performance and durability properties, including strength, elastic modulus, permeability, freeze-thaw, scaling, thermal expansion, creep, shrinkage, and others.

Savings / Benefits: Application of HPC should result in structures designed and built having lower labor and material costs, requiring less maintenance, and having longer service lives. As a result of designing HPC in the Rte. 412 bridge, girders per span were reduced from 6 to 4, and the deck should have an extended service life.

Status / Results: The Rte. 412 HPC bridge was constructed during the summer of 2001. Laboratory testing of HPC mix samples and in-service structural monitoring has taken place since that time and will conclude late summer 2003. A final report will follow.

Implementation: Currently, MoDOT incorporates HPC into structural designs on a case-by-case basis where determined to be appropriate and cost-effective. Results of this study are anticipated to provide designers with additional information, which should facilitate further application of HPC in MoDOT bridge designs.

RI 00-021 & RI 00-031 Laboratory and Field Testing of Fiber Reinforced Polymer Composite Bridge Decks & Laboratory and Field Testing of a Fiber Reinforced Polymer Concrete Bridge Deck (UMR)

Purpose: The overall objective of this research project was to conduct an extensive study of the behavior and use of glass fiber reinforced polymer (GFRP) and carbon fiber reinforced (CFRP) materials for bridge construction. In particular, GFRP honeycomb sandwich panels were used as bridge panels and steel-supported bridge deck panels and CFRP and GFRP bars were used as internal reinforcement for precast concrete bridge panels. More specifically, this research program provides laboratory characterization of FRP bars and FRP-reinforced concrete (FRP-RC) panels, laboratory characterization of FRP honeycomb sandwich panels and their constituent materials, in-situ characterization of FRP-RC panels and FRP honeycomb sandwich panels, investigation of the durability performance of FRP bars and FRP honeycomb



sandwich panels, and evaluation of construction techniques for FRP-RC panels and FRP honeycomb sandwich panels.

Savings / Benefits: Investigations focused on determining factors for design using FRP materials in bridge construction, in particular, the necessary material properties, design parameters (e.g., live load impact factors and wheel load distribution factors), and design protocols (e.g., serviceability predictions) were the focus of this research with the ultimate goal being the assistance of industry in developing material and design standards for FRP materials. In this way, the materials may become a viable alternative to traditional materials for the improvement of our Nation's deteriorating infrastructure.



Status / Results: The research program consisted of a series of investigations in the field and in the laboratory. Four short-span bridges were installed so as to outline the construction-related issues associated with the use of these materials. The bridges are located in a residential area of St. James, Missouri; each bridge utilizes FRP materials in a different structural system to investigate the feasibility of using FRP in each of these applications. In-situ load tests of the constructed bridges were conducted to illustrate the behavior of the overall structures, in terms of panel behavior and installation details. Load testing following construction and at later ages was undertaken allowing the examination of the bridges' long-term performance under ambient outdoor environmental conditions. Finally, the third investigative series dealt with the laboratory characterization of these materials, considering both the overall panel behavior and the individual materials. A report , RDT02-012, was published in October 2002 covering the lab testing and construction of the four bridges. Load testing of the bridge decks was done after construction and one year later. Follow up of the condition of the FRP panels and the FRP reinforced concrete deck will be done during regular bridge inspections every two years.

RI 00-027 Stainless Steel Reinforcing Bars in Bridge Decks



Purpose: The main objective is to extend service life of bridge decks. This study will determine if using stainless steel reinforcement in place of epoxy-coated reinforcement in bridge decks will reduce corrosion and extend the service life of bridge decks long enough to make them cost effective. This will be tracked by doing yearly checks on fiber optic chloride sensors, permeability, and half-cell potentials along with visual inspections on the bridge deck to determine the extent of corrosion of the rebar.

Savings / Benefits: Although the stainless steel reinforcing bars are more expensive than epoxy coated reinforcing bars, they are designed to more than double the service life of the epoxy-coated reinforced bridge decks. By reducing the corrosion, the need for patches and overlays would also be reduced, which would result in decreased life cycle costs. This would therefore reduce the overall costs of maintaining the bridge.

Status / Results: The Rte. 6 Grundy County Bridge using stainless steel reinforcement was opened in 2001, and a construction phase report was published in February 2003. An interim report will be completed in 2005. Future monitoring will be done, and reports will follow as appropriate. In the future, a final report will be prepared that will discuss project findings and overall performance of the stainless steel reinforcement versus the epoxy-coated reinforcement.

RI 00-061 Galvashield XP Embedded Galvanic Anodes to Inhibit Corrosion in Bridge Decks

Purpose: The objective of this study is to prevent new concrete repairs from being affected by early corrosion of rebar. Approximately 2,750 Galvashield XP anodes were installed on 26 bridges in this project, to minimize or reduce the onset of future corrosion in these bridges and to reduce the effect of "ring anode" corrosion associated with concrete patch repairs.

Savings / Benefits: Stopping the "ring anode" corrosion effect will prolong the life of the concrete patch repairs. The cost of having to repair these areas in the future will be eliminated, and the health of the rest of the concrete decks will be enhanced by not allowing the deterioration to spread from repaired areas.

Status / Results: The installation was completed during construction in 2002. Three locations of deck edge repairs with the Galvashield XP anodes were instrumented to allow the reading of current outputs of the anodes. After the first year, readings will be taken annually until 2006 to verify adequate current flow for cathodic protection. Three deck edge locations on the twin bridges directly across from those instrumented areas were patched without the Galvashield XP anodes. The condition of the concrete patches will be annually compared between those with anodes installed and those without. Additionally, one deck patch was instrumented so that current readings can be taken and annually compared to nearby patches without anodes. A short summary report was made on the installation of the anodes, but a final report will not be published until 2006.



RI 01-028 Implementation Issues of Metallic Dampers for Seismic Retrofit of Highway Bridges (UMR)

Purpose: This is a contract research study with the University of Missouri – Rolla. The purpose of this project is to address several issues related to the implementation of metallic dampers in steel girder bridges with rocker bearings for improved seismic performance. Specifically, the project is aimed to establish design equations for load-carrying capacity of rocker bearings and for damping property of metallic dampers consisting of tapered rods. Another goal is to address the effect of cross frames on the damping property of dampers, and to validate previously-proposed design procedures for bridge systems including metallic dampers.

Savings / Benefits: Metallic dampers provide an economic solution to upgrade deficient bridges into compliance with current design guidelines in the New Madrid Seismic Zone (NMSZ). Additionally, retrofitted bridges will perform better in case of the next big earthquake in the NMSZ. As a result, these bridges will provide critical links for emergency vehicles to transport disaster relief to affected areas in time.

Status / Results: The test specimens have just been fabricated after problems obtaining the 36 ksi steel rods needed, and testing to derive the design equations has also begun.

RI 01-044 Laboratory Testing of PCC Bridge Deck Mixes

Purpose: The objective of this investigation is to develop and test different Portland Cement Concrete (PCC) mix designs for MoDOT bridge decks to minimize shrinkage cracking while maintaining other performance and workability characteristics.

Savings / Benefits: Reduced cement and addition of supplementary cementitious materials decreases the cost of the mix by approximately \$7.50/yd³. The changes made to the concrete bridge deck design are proposed to mitigate early cracking, which will decrease the rate of deterioration and increase the life of the bridge.

Status / Results: Three mix designs were selected from this study to be implemented on pilot projects in the field. The mix design utilizing 25% ground granulated blast furnace slag (GG-BFS) and 15% Class C fly ash has been poured successfully on three projects as of June 2003. Mixes containing 40% GGBFS or 25% Class C fly ash are also options for lowering the cracking potential of bridge decks. MoDOT Construction, Materials, and Bridge units plan on implementing new bridge deck mix designs into standard specifications by the 2004 construction season.



RI 02-002 Steel-Free Hybrid Reinforcement System for Concrete Bridge Decks: Phase I (UMC & UMR)

Purpose: The main objective of this collaborative research is to develop a nonferrous hybrid reinforcement system for concrete bridge decks using continuous fiber reinforced polymer (FRP) rebar and discrete randomly distributed polypropylene fibers with a view to eliminate corrosion in bridge decks. Fiberglass FRP (glass FRP or GFRP) rebar will be used in the top mat of reinforcing, and carbon fiber FRP (CFRP) bars will be used in the bottom mat. The fiberglass is less expensive than the carbon fiber but is still corrosion resistant while the CFRP has higher strength. The polypropylene fibers in the mix should help keep the concrete from cracking.

Savings / Benefits: Limited service life and high maintenance costs are associated with corrosion, fatigue, and other degradations of highway bridges and reinforced concrete structures. The combination of FRP reinforcement with the use of polypropylene fibers offers an innovative hybrid bridge deck system that can eliminate problems related to corrosion of steel reinforcement while providing requisite strength, stiffness and desired ductility.

Status / Results: A Research Advisory Committee consisting of representatives from MoDOT, UMC, UMR, the FRP rebar manufacturer and fiber manufacturer was formed to oversee the progress of the project, and has met for the second time. Concrete cylinder and beam tests and pull out tests on the GFRP and CFRP bars are being done at UMC. UMR is doing load tests before and after strengthening. Successful completion of this project will lead to fabricating and testing of a full-scale, steel-free slab. The project will be completed by June 2004.

RI 02-007 Strengthening Martin Springs Outer Road Bridge, Phelps County (UMR & Kansas DOT)

Purpose: The proposed project aims at demonstrating the feasibility of fiber reinforced polymer (FRP) systems for the flexural strengthening of concrete bridge structures. The bridge selected for this demonstration project is the three-span concrete slab bridge located on Martin Springs Outer Road in Phelps County. This bridge is composed of a 14 in thick solid reinforced concrete slab for which posting can be removed as the result of the proposed strengthening scheme.

Savings / Benefits: In the state of Missouri and surrounding Mid-America states, several bridges exhibit similar conditions, and are in urgent need of strengthening to remain functional.

Status / Results: This demonstration will consist of three major tasks; (1) design of strengthening scheme, (2) load tests before and after strengthening, and (3) field construction. All of these steps have now been completed, and a final report will be submitted in the summer of 2003.



Implementation: It is envisioned that this strengthening technique will lead to a bridge strengthening protocol for consideration by MoDOT for future applications.

RI 02-010 Post Earthquake Damage Evaluation of Bridge Structures (UMR)

Purpose: Many bridges in Southeast Missouri are vulnerable to earthquake effects originating from the New Madrid Seismic Zone. For example, along US 60, the designated emergency vehicle access route, 42 of 55 bridges were designed without seismic considerations. Non-destructive evaluation (NDE) methods will be found that are suitable for examination and evaluation of the bridge damage level resulting from a major earthquake. The feasibility of using microwave technology to detect plastic deformation of re-steel within concrete will be studied. Also, inspection techniques and retrofits for bridge parts such as steel diaphragms will be tested.

Savings / Benefits: The developed and / or validated techniques in this study will provide viable tools for rapid evaluation of bridge conditions immediately after an earthquake so that emergency vehicles can be assured to pass the bridges safely. These techniques are also applicable in the assessment of structural conditions of truck- or ship-impacted bridges.

Status / Results: The study is expected to take two years, and is scheduled to be completed in May 2004.

RI 02-011 Seismic Retrofit Techniques for Bridge Cap Beams, Columns and Connections (UMR)

Purpose: Multiple column bridges are widely used in construction of highway bridges. In earthquake prone areas like Missouri and Alaska, these reinforced concrete components have to be strengthened in order to dissipate the energy to prevent failure. MoDOT and Alaska DOT (ADOT) pooled funds together for this research. Based on a recent assessment of four highway bridges in the New Madrid Seismic Zone (NMSZ) located in the state of Missouri, it was found that two (new St. Francis River Bridge and Old Wahite Ditch Bridge) out of four bridges may potentially collapse due to insufficient flexural / shear strength in cap beams. In Alaska, because of ice flows, most of the columns are built stronger than the cap beams. A full scale model will be built and tested to come up with good seismic retrofit strategies for both Missouri and Alaska's multiple column bridges.



Savings / Benefits: The proposed retrofit schemes will address the following requirements: (1) simple implementation in the field, (2) maintenance of minimum levels of traffic disruptions, and (3) durability. The research results of this study can be used to effectively retrofit inadequate bridges along US 60 and other emergency routes. These efforts will ultimately reduce the potential loss of lives and property damage in Southeast Missouri in the event of a catastrophic earthquake event.

Status / Results: The study is expected to take two years, and is scheduled to be completed in May 2004.

RI 02-019 New Placing & Curing Specifications for Bridge Decks

Purpose: In 2002 a new placing and curing specification was implemented for concrete bridge deck construction. The new specification was developed in an effort to minimize early cracking observed in several of Missouri's new bridge decks, a problem recognized to lead to poor deck performance, high maintenance costs, and decreased service lives. Requirements for lower placing temperatures, application of an interim curing compound, and an extended 7-day wet cure are included in the new specification and are expected to result in less cracking in bridge decks. This particular study involves monitoring performance of bridge decks constructed with the new specification to validate improved deck performance.

Savings / Benefits: Reduced cracking in bridge decks should result in improved performance, less corrosion of steel reinforcement, lower maintenance costs, and extended service lives producing overall lower bridge deck life-cycle costs.

Status / Results: The bridge deck cracking evaluation program was initiated in 2002, and will continue through 2004. To date, results indicate that the new specification has resulted in less cracking in bridge decks.



Implementation: The new specification has been implemented since 2002. The results of this study will be used to recommend any needed changes to the specification.

RI 02-022 Preservation of Missouri Transportation Infrastructure: Validation of FRP Composite Technology Through Field Testing (UMR)

Purpose: Fiber reinforced polymer (FRP) composite technology continues to advance as an alternative to conventional structural materials because of its strength, lightweight structure, corrosion resistant capability, and versatility as a structural material. Through strengthening five structures (currently rated structurally deficient) with externally bonded carbon FRP laminates, this project with the University of Missouri-Rolla (UMR) should validate FRP composite strengthening technology and result in development of design, materials, and installation specifications written and formatted for potential AASHTO adoption.

Savings / Benefits: Application of FRP composite strengthening technology offers a potentially cost-effective means of strengthening structures rated structurally deficient. The speed and ease of FRP materials installation should result in significant time-savings during construction also causing minimal to no traffic disruption.

Status / Results: The contract for this 5-year project with UMR was signed in early 2003. FRP strengthening improvements to the five structures are expected to take place during the summer of 2003. Monitoring and validation efforts will then take place throughout the duration of the study concluding with a final report prepared in 2008.

Implementation: It is anticipated that the results of this study will provide FRP composite strengthening design, materials, construction and maintenance guidelines for future AASHTO adoption and MoDOT implementation.

RI 03-002 Predicting Chloride Ion Penetration of Hydraulic Cement Concrete by the Rapid Migration Test



Purpose: The Rapid Migration Test (RMT) is performed on hardened concrete 28 days after the cylinders have been cast, compared to 56 days for the Rapid Chloride Permeability test (RCP). The 4"X8" concrete cylinders have to be cut into three 2"X4" diameter "pucks" and placed in a vacuum chamber for three hours dry and one hour wet for both test methods. After vacuuming the concrete pucks, they are then saturated for 18 (+/- 2) additional hours under normal atmospheric conditions. The pucks are placed in rubber sleeves and then placed in a test chamber of sodium chloride solution for the RMT and

a solution of sodium hydroxide is poured on top of the puck inside the rubber sleeve. Voltage is applied to each specimen for 18 hours before removing the pucks from their sleeves and broken in half. A solution of silver nitrate is sprayed on the broken face of each puck and the chloride penetration is then measured using a steel ruler. A simple equation is used to compare the rate of penetration found during the RMT procedure to the coulombs passing found during the RCP tests.

Savings / Benefits: For many years, MoDOT has been using AASHTO T277, Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration, to test concrete used in highway construction. The variability of the results of T277 has proven to be suspect, especially between the testing labs. AASHTO TP 64 was introduced to replace T277 in hopes of developing a test method with fewer variables and with the ability to visually observe the penetration of the chloride ions. The projected coefficient of variability for TP 64TP 64 (16%) is lower than T277 (25%). The improved accuracy of the Rapid Migration test will lead to better conclusions about concrete durability.

Status / Results: In February 2003, Research, Development, and Technology (RDT) were approved to fabricate the test equipment for TP 64. Following material procurement the testing apparatus was completed in May. Testing began in August. The test equipment performed as expected. We are currently working on a schedule to use the RMT extensively along with the Rapid Chloride Permeability test.

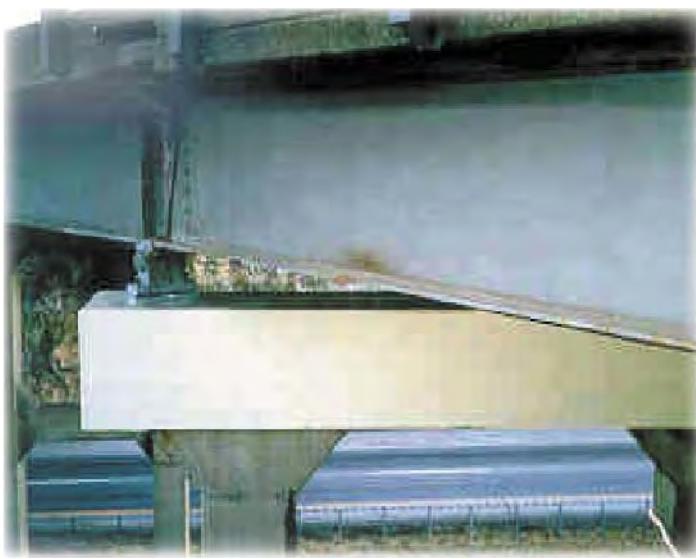
RI 92-004 Statewide Study of Cathodic Protection Systems

Purpose: The objective of this study is to provide guidance for MoDOT's program for cathodic protection (CP) of bridge decks as well as looking at new CP technology.

Savings / Benefits: Cathodic protection is the only known means to stop corrosion of uncoated steel reinforcement. It will remain an option for rehabilitating existing bridges as long as uncoated bars remain in our bridges, or alternate reinforcing materials are not practical enough to replace steel. Besides the eighty bridge decks using impressed current systems, two projects using galvanic or passive anodes (no AC power is needed to run the system) are under way. These projects; RI98-036, Zinc-Hydrogel Anode and RI00-061, Galvashield XP Anodes are described elsewhere in this report

Status / Results: A bridge rehabilitation and widening project on I-70 in Kansas City is underway that had 14 existing bridge decks with cathodic protection systems in place for 16-17 years. On 5 of the 14 bridges, the CP system had driven the chlorides away from the rebar enough that active corrosion was no longer taking place, and the system was replaced with a dense concrete overlay only. The other 9 bridges still showed questionable amounts of chlorides near the rebar. The cathodic system on these is being replaced with a new titanium mesh CP system and expected to add at least another 20 years to the life of these large concrete superstructure bridges.

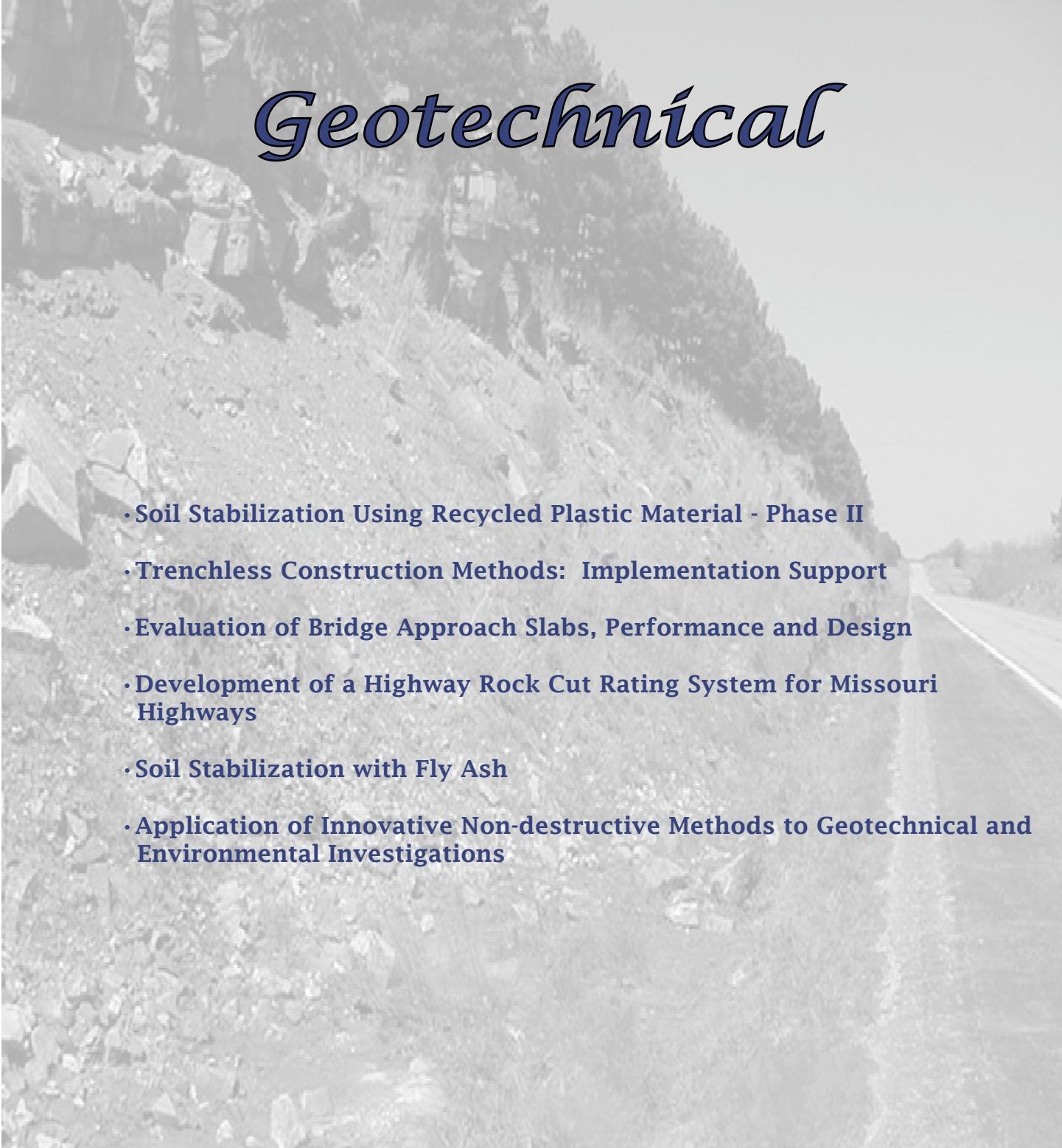
RI 98-036 Cathodic Protection of Pier Caps Using Zinc Hydrogel Anode (UMC)



Purpose: The objective of this study is to determine the effectiveness of applying galvanic cathodic protection (CP) to bridge pier caps, which have required continued concrete patching due to salt water leaking through deck joints.

Savings / Benefits: Hundreds of thousands of dollars is spent in repairs on reinforced concrete substructure units. Even if the leaking problems that cause damage are fixed, once salt from snow and ice control reaches the rebar it will continue to corrode, and this expensive patching will come out again and need a second or even third repair. CP is the only known way to stop rebar corrosion in salt contaminated concrete.

Status / Results: Patching of seven substructure units (4 pier caps and 3 abutments) was finished in fall 1999, and the Zinc-Hydrogel anode was applied. Field inspections will be made quarterly until 2004 to check the physical condition of the piers and the current flow between the anode and the rebar. Construction phase and progress reports were made in 2002. Inspection reports will be made annually and an evaluation report after five years. Expected life of the anode is 10 to 15 years. After one year, a leaking joint and bad repair concrete made it necessary to replace the anode at one pier cap. After 4 years, the anode is eaten away in many locations where it is exposed to water and is not expected to make the 7 years that the manufacturer has warranted it for.



Geotechnical

- Soil Stabilization Using Recycled Plastic Material - Phase II
- Trenchless Construction Methods: Implementation Support
- Evaluation of Bridge Approach Slabs, Performance and Design
- Development of a Highway Rock Cut Rating System for Missouri Highways
- Soil Stabilization with Fly Ash
- Application of Innovative Non-destructive Methods to Geotechnical and Environmental Investigations

RI 98-007B Soil Stabilization Using Recycled Plastic Material - Phase II (UMC)

Purpose: The project is the second phase of an earlier research project that evaluated the feasibility of permanently repairing roadway slope failures by driving long, slender members, referred to as pins, into the re-graded slope. The pins are made from recycled plastics and are a desirable material to use for various ecological reasons. The pins are instrumented in this project to evaluate their performance. This phase of the project is to expand the variety of soils to be stabilized with this treatment, continue to monitor the existing field installations, and to advance the economic evaluation of the recycled plastic pin technology.

Savings / Benefits: Repeated attention from MoDOT maintenance forces is required for many small slides that occur around the state. A permanent solution would save time and money and, in some cases, provide support to the embankment to prevent eventual pavement distress related to slope failure.

Status / Results: The University of Missouri-Columbia is conducting this project. Field installation at the two final sites was completed in January of 2003. Nearly all instrumentation was in place at that time. Monitoring of in-place instrumentation continues.

Implementation: A future phase of this project will result in final design documents and construction procedures. At that time, a decision will be made to undertake this repair method with MoDOT forces, or to contract this type of work.

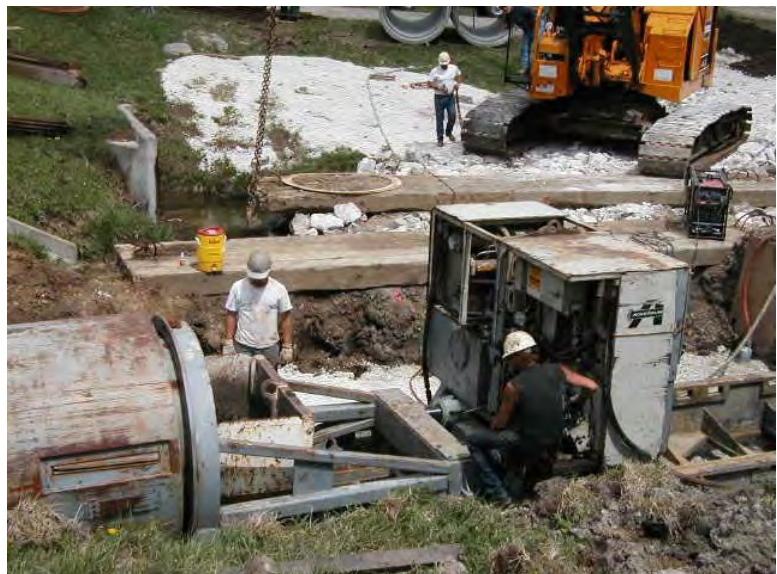
RI 02-003 Trenchless Construction Methods: Implementation Support (UMC)

Purpose: The demand for installing new underground utility systems in congested areas with existing utility lines has increased the necessity for innovative systems to go underneath in-place facilities. Environmental concerns, social costs, new safety regulations, difficult underground conditions and new developments in equipment have increased the demand for trenchless technology. In recent years, there has been remarkable progress in development of new trenchless technology equipment. However, the preparation of design guidelines, construction specifications, inspection and testing, etc. have not kept pace with these new developments. The scope of work for this project includes trenchless construction methods (TCM's), engineering analyses, method evaluation for a specific application, preparation of construction documents, review and completion of current MoDOT construction guidelines and specifications, course material, and course offerings for MoDOT engineers, construction workers, permit inspectors and other MoDOT personnel.

Savings / Benefits: Improved equipment, procedures, specifications and training will result in better quality installations which are less likely to fail in some fashion necessitating costly repairs.

Status / Results: The review of MoDOT guidelines is complete, and most of the contract documents have been finalized. Training was presented at three locations around the state in May of 2003.

Implementation: Following preparation of the final report, changes are expected to be incorporated in MoDOT trenchless construction guidelines.



RI 02-033 Evaluation of Bridge Approach Slabs, Performance and Design (UMR)

Purpose: Current construction practices often result in settlement of approach slabs near bridges. As a consequence there is often times a bump at the ends of a bridge. In some cases the settlement leads to cracking in the approach slab. Slight settlement in the approach slab is responsible for reduced ride quality of the facility, and severe settlement may create an unsafe condition. MoDOT districts have spent considerable time and money in an effort to repair these settled slabs with varying degrees of success. A MoDOT task force recommended the problem be researched. The purpose of this project is to identify and quantify the failure mechanisms observed at the approach slabs and to make recommendations to avoid this type of failure in the future.

Savings / Benefits: An improved design will result in pavements that will last longer and will not require the types of repair that some current approach slabs need. The ride of the facility, and possibly the safety, will be improved. The reduced incidence of settlement repairs will also save time and money.

Status / Results: The University of Missouri-Rolla is conducting this project. Results of a resident engineer survey have been received and tabulated. Settlement calculations using the finite element program PLAXIS were completed for two bridges. Other field exploration was completed as outlined in the work plan. The project completion date is September 30, 2003.

Implementation: Upon completion of this project, recommendations will be made to improve the current design of the bridge / pavement system to eliminate the problem.

RI 02-046 Development of a Highway Rock Cut Rating System for Missouri Highways (UMR)

Purpose: The purpose of this study is to develop a rating system, designed specifically for Missouri, which will identify criteria that are important, yet quick and easy to measure to assess the stability of rock cuts along Missouri's highways. Rock cuts will be analyzed through imaging software. The criteria will be sorted by risk, consequence and repair costs, so that a priority for maintenance or remediation may be determined. A system that allows quick assessment and prioritization of potential rock cut failures will help provide safe transportation for all who use the highways.

Savings / Benefits: The system will allow engineers to identify areas that need attention to prevent failures. Preventing failures will reduce traffic delays, property damage and even possible fatalities.

Status / Results: The system is being developed by the University of Missouri-Rolla. The various criteria have been established, and work is continuing on refining the individual factor values to be used in the rating system. Thirty-eight sites have been assessed with current factor values with good preliminary results.



Implementation: As the system develops, MoDOT engineers will be able to review the system and make comments for improvements. When the system meets MoDOT's approval, training will be held to educate district personnel on its use.

RI 00-019 Soil Stabilization with Fly Ash

Purpose: The purpose of this investigation is to evaluate the benefit of soil stabilization to initial pavement smoothness of various base and subgrade designs on U.S. Route 36 in Caldwell County. Test sections that are modified with fly ash, hydrated lime, or lime-kiln dust will be compared to a control section with Type 5 base and a control section with two-foot rock base.

Savings / Benefits: The initial smoothness of a pavement is believed to contribute to a longer lasting pavement requiring less maintenance than a rougher pavement. The reduced maintenance and repair costs, along with the expected longer life of the pavement, will offset the cost of subgrade modification and is likely to lead to a lower life cycle cost.

Status / Results: The initial report has been written and is currently under review. The pavement will be monitored and evaluated on an annual basis until 2006, at which time a decision will be made as to what further monitoring and evaluation is necessary.

Implementation: Future projects may be built using soil stabilization, based on the construction and performance of the pavement. If warranted by performance or life cycle cost, the department's specifications may be altered to require stabilization in some areas of the state.

RI98-014, RI98-015, RI98-017, RI98-019, RI00-012 Application of Innovative Nondestructive Methods to Geotechnical and Environmental Investigations (UMR)

Purpose: This research effort with the Department of Geology and Geophysics at the University of Missouri-Rolla (UMR) was initiated to evaluate the application of the following nondestructive geophysical methods for subsurface exploration: high-resolution shallow reflection seismic, ground penetrating radar (GPR), electromagnetic (EM), and electrical resistivity. In contrast with typical intrusive procedures, which can be time consuming, damaging and costly, nondestructive geophysical methods can potentially provide transportation engineers with reliable subsurface information much more efficiently and with less risk. Work with UMR included several individual geophysical site characterization studies, where conditions, objective and geophysical methodologies varied from study site to study site.

Savings / Benefits: Nondestructive geophysical methods can provide valuable, efficient and cost-effective information regarding subsurface materials and conditions for transportation applications. This information can be essential during project design and construction, as well as, when immediate surface problems occur and safe, nondestructive and timely methods are needed for obtaining subsurface information.

Status / Results: Report RDT03-008, Application of Innovative Nondestructive Methods to Geotechnical and Environmental Investigations, was published this year. The case studies demonstrated that non-invasive geophysical technologies, when applied appropriately, can often provide important and cost-effective information about the geotechnical nature of the shallow subsurface.

Implementation: Protocol for the application and selection of appropriate geophysical methods was established as a result of this effort.

Operations

- Ultra-Thin Hot Mix Asphalt Overlay
- URETEK Pavement Leveling and Undersealing
- AC15-5TR Chip Seal
- Non-destructive Detection of Defects in Snow Plow Wearing Surfaces
- Evaluation and Implementation of the Air Void Analyzer in Missouri
- Long Term Maintenance of Load Resistance Factor Design (LRFD) Specifications
- Transportation Asset Management Research Program
- Design of Bridges for Security
- Material and Construction Optimization for Prevention of Premature Distress in PCCP

PD 98-055 Ultra-Thin Hot Mix Asphalt Overlay

Purpose: The project's purpose is to determine if the Ultra-thin hot mix asphalt overlay utilized primarily in urban, high volume locations, will improve pavement conditions where frequent wet pavement accidents occur and provide longer asphalt pavement life cycles. The overlay is expected to maintain friction values during wet weather due to its open-graded mix design. Instead of fallen precipitation draining across the top of the surface creating a thin sheet of water, with the ultra-thin overlay, precipitation drains down through the surface to a liquid membrane placed under the mix. Since moisture is not traveling across the surface to drain, hydroplaning is reduced. In addition,

without excess moisture available on the surface to be thrown up by vehicle tires, visibility is also increased with the overlay.



Savings / Benefits: The reduction in wet pavement accidents and improved customer satisfaction is the goal of this project. The material initially started out to cost about two to three times that of a regular one-inch hot mix overlay surface. However, recently the cost of the overlay has come down in price to be about 1½ times the cost of a one-inch hot mix overlay.



Status / Results: The material was initially placed at two locations, I-29 / I-229 north junction placed in 1998 and another at the I-29 / I-229 south junction placed in 1999. Yearly evaluations are currently being performed. Completion of the evaluation for the I-29 / I-229 north junction section is scheduled for October 2003.

Implementation: Due to favorable results from the initial test sites, several other locations within Missouri have been receiving the ultra-thin hot mix asphalt overlays. The districts are beginning to use the

surface as a preventive maintenance measure. One location on Rte. 76 in Taney County, two locations on Rte. 13 in Greene / Polk Counties and another location in Greene County at the end of the ramp from southbound U.S. 65 to westbound U.S. 60 were placed in 2001. The Rte. 13 locations were milled off due to incorrect placement / mix design. A section of I-35 in Clay County, several locations around the St. Louis area on Rte. AB, Rte. 47, Rte. 100, and I-44 in Franklin, Crawford and Phelps counties were placed in 2002. More exposure of the overlay to varying conditions and pavements will aid in preparing the final report at the completion of the study. When placed correctly, the surface has seemed to perform well in reducing accidents and increasing visibility during wet pavement conditions.

PD 98-072 URETEK Pavement Leveling and Undersealing

Purpose: This product is currently being evaluated to provide an alternative to the existing mudjacking method where lime, cement, and water slurry have been used to level and underseal pavements. Many times after mudjacking, the repair crew has to come back to perform additional mudjacking. So far, with the URETEK method, return visits have not been needed to repeat the application at the same locations.

Savings / Benefits: Bids submitted for in-place material have been ranging from \$5.50 - \$6.50 per pound. Under normal lifting and undersealing conditions, the amount of material needed to accomplish this has been found to be between 0.5 - 0.75 pounds per square foot. Assuming averaged

values and that the void under the pavement isn't very large, the cost calculates to be \$3.75 per square foot to raise and underseal the pavement. This method is more expensive than the conventional mudjacking method; however, lifting pavements using the mudjacking method have proven to be mostly unsuccessful with most attempts causing more damage to the pavement. In addition, a hidden benefit so far has been that once the URETEK method has been used, additional applications are not needed, eliminating future costs associated with return visits.



Status / Results: The product seems to be performing well at the original trial site on Rte. 63 near Ashland. However, RDT is still evaluating the Ashland site and even though the end of the trial isn't until 2004, we are expecting an RDT final report on the performance of URETEK in late 2003 to early 2004.

Implementation: A generic specification has been developed for MoDOT districts to use this product for pavements in need of lifting to grade and undersealing.

PD 02 - 014 AC15-5TR Chip Seal

Purpose: This product is being evaluated to provide an alternative economical option for a preventive maintenance treatment for high volume roads.

Savings / Benefits: Savings will be realized when placing this treatment for preventive maintenance applications. Currently, for high volume routes, options are limited to more expensive treatments such as hot-mix overlays and micro-surfacings. This chip seal process is estimated to cost approximately $\frac{1}{2}$ the cost of hot-mix or micro-surfacings.





Status / Results: This product was placed at the end of May 2002. To date, it is performing well with some minor raveling occurring at the center line. "Before" photos of the pavement show that higher deterioration levels were present along the center line of the roadway. From this, a possible reason for center line raveling may be due to the oil being absorbed by the porous pavement leaving less oil on the surface to bond the chips to the pavement. RDT will continue to monitor the performance of the treatment for any other problems.

RI 01-023 Non-destructive Detection of Defects in Snow Plow Wearing Surfaces

Purpose: The purpose of this project is to use ultrasonic testing to determine the source of defect propagation in carbide/steel snowplow blade inserts and qualify a Non Destructive Testing technique that will: (1) locate, quantify, and size defects as well as determine whether or not defects originating in the manufacturing process have an impact on blade service life, (2) monitor in-service blades to determine the rate of carbide insert and bond breakdown in the field to assess acceptability of various blade insert materials, and (3) evaluate various carbide insert configurations in the field that best meet MoDOT snow removal requirements.



Savings / Benefits: Savings will be realized through the extended life of snowplow blades when the cause and subsequent solution to the premature failure of our snowplow blades is determined. Working on this project has also brought other aspects to our attention that were not considered in the original evaluation, such as the use of multiple blades and plow configurations, i.e. attack angle of the blade and plow angle. Including these other aspects should lead to a more thorough evaluation



Status / Results: The report is in the final stage at this time. We have shown that ultrasound examination can divulge pre-service and in-service defects in single layered carbide chip insert blades. The inspection of these blades in the lab is fairly straightforward, and the techniques work well in the field as long as the blade surface of the inspection area is not damaged. We were able to locate and size some types of defects, as well as monitor in-service blades to determine carbon breakdown in the field. The first opportunity to observe the blades in operation was during the 2002-2003 winter season. A significant amount of data was

gathered during this season in which it was determined by RDT that manufacturing defects found by nondestructive testing did not appear to be detrimental to the service life of the blades. RDT is currently evaluating the performance of several plow blades in different configurations and will continue to monitor and observe the snowplow blades in upcoming winters.

RI 03-004 Evaluation and Implementation of the Air Void Analyzer in Missouri



Purpose: The air void analyzer (AVA) is a fairly new piece of equipment, which has the capability of determining the structure of the air void system in fresh concrete, as opposed to conventional air meters, which only measure air content in fresh concrete. The resistance of concrete to freezing and thawing is better characterized by its air void system (e.g. spacing factor and specific surface) than simply its total air content. In the past, the structure of the air void system could only be determined once the concrete had hardened, which then requires a specialized operator and is very time consuming. The AVA offers an

ideal means of immediately determining the adequacy of the air void system in fresh concrete, thus, allowing immediate mix and placement adjustments during construction. This project will include evaluation of the AVA equipment operation in the field, field-testing of AVA concrete samples, and pursuing a correlation between AVA results, air void analysis of hardened concrete, and freeze-thaw durability.

Savings / Benefits: The AVA equipment should provide timely and valuable data regarding the structure of the air void system in concrete, allow better control, and improve the durability and quality of the concrete placed.

Status / Results: AVA equipment has been recently purchased, and testing, as laid out in the work plan, is underway. Missouri is also participating on the AASHTO AVA Technology Implementation Group (TIG) initiated to pursue nation-wide implementation of the AVA.

Implementation: Following successful evaluation of the AVA equipment, recommendations and a specification will be provided for its implementation. Implementation of the AVA will likely be most effective on QC / QA paving projects where maintaining strength while ensuring adequate air is critical and on performance related specification projects where measures taken during paving are needed to quantify future pavement performance.



Pavements

- Measurement of Granular Base Permeability
- Smoothness of PCC and Asphalt Pavements
- Dowel Bar Inserters
- Longitudinal Keyway Joint Investigation
- Subgrade / Embankment Compaction Study
- Precast Concrete Panels in New Highway Construction
- Concrete Maturity Test Method
- New PCC Pavement Design Study (System Preservation)

RI 01-006 Measurement of Granular Base Permeability

Purpose: The objective of this study is to determine permeability of pavement bases that Missouri uses in new construction projects. Several issues regarding the effectiveness of Missouri's new base types need to be explored. The first is permeability of the Type 5 base. No in-situ and very little lab permeability testing was ever performed.

The other issue is permeability of rock base.

While it is generally believed from field experience that it does drain well, no attempt has ever been made to quantify that ability. An auxiliary issue to these is the variability of permeability from site to site.



Savings / Benefits: Modifying the current design specifications for Missouri's granular bases to optimize permeability and stability will result in longer lasting, more cost-effective pavements.

Status / Results: The University of Missouri-Columbia has completed an initial report on the effectiveness of Type 5 base. Based on lab and field data, it is clear that Type 5 base has poor drainage characteristics. It has yet to be determined how this affects the overall performance of the pavement above. More data needs to be collected to properly evaluate the rock fill base.

RI 01-045 Smoothness of PCC and Asphalt Pavements

Purpose: The objective of this investigation is to determine how initial smoothness of a pavement after construction affects future ride and pavement performance. The data collected from this study will be analyzed for general trends to determine how the initial smoothness of pavements affects future ride and pavement performance. The question "Does smoother pavement perform better and last longer?" must be answered in order to justify the incentive / disincentive measures in construction contracts.



Savings / Benefits: This investigation is intended to justify cost effectiveness of constructing smooth pavements.

Status / Results: A lightweight profiler is in the process of being purchased in order to measure pavement smoothness on numerous older pavement projects statewide. Initial construction data and ARAN data will also be used to compare the smoothness of all pavements and determine how well each project is performing.

RI 01-049 Dowel Bar Inserters



Purpose: The purpose of this study was to determine the accuracy of dowel bar inserters in a PCC paving project and to develop acceptance criteria for future dowel bar placement with dowel bar inserters. Dowel bar inserters (DBI) on concrete paving equipment eliminate the need for manually placing dowel bar baskets. DBI performance was evaluated at a paving project on U.S. 60 near Van Buren.

Savings / Benefits: A cost savings should be realized with DBI use through the reduced labor and material costs of placing dowel baskets.

Status / Results: The project was completed in the summer of 2002. Ground penetrating radar (GPR) measurements of ten transverse joints with dowel basket assemblies and ten transverse joints fitted with the DBI revealed comparable performance. A final report was completed with recommendations and special provisions for allowing this particular make of DBI on future paving projects.



RI 01-050 Longitudinal Keyway Joint Investigation

Purpose: The objective of this investigation was to determine the effectiveness of keyways at longitudinal construction joints in PCC pavements. Keyways are a traditional means of providing load transfer at longitudinal construction joints. Missouri has used them for many years. The primary question that's been raised is, "Are they really needed?". Since tie bars are used in conjunction with keyways there appeared to be a redundancy in load transfer. Also, MoDOT's newer PCC design calls for widened driving slabs, which reduce edge stresses and help negate the need for longitudinal load transfer.



Savings / Benefits: Eliminating keyways at shoulders should simplify construction and provide a modest cost savings in the price of concrete paving.

Status / Results: ERES/ARA Consultants completed a finite element modeling (FEM) investigation of keyway performance in longitudinal joints. The results of this modeling, combined with the visual study of cores taken at longitudinal joints with keyways, concluded that keyways were not necessary at widened driving lane / shoulder interfaces. Standard plan drawings were modified to reflect these conclusions.

RI 03-006 Subgrade / Embankment Compaction Study

Purpose: The purpose of this study is to find alternate testing means to nuclear gauges for construction acceptance of subgrade and embankment compaction. Traditionally, density and moisture content have been the acceptance criteria for compaction, however; neither is an actual measure of performance. The dynamic cone penetrometer (DCP), which measures a type of soil shear resistance, will be used at several pilot project locations as an alternate to density measurements. Moisture content will also be measured as a check to ensure conditions are close to optimum. The moisture content device will probably be based on time domain reflectometry (TDR) technology.

Savings / Benefits: Long term cost savings will be realized through the elimination of nuclear gauge testing, calibration, and technician training. Less tangible benefits are the reductions in stress from not having to continually monitor the condition and location of radioactive equipment.

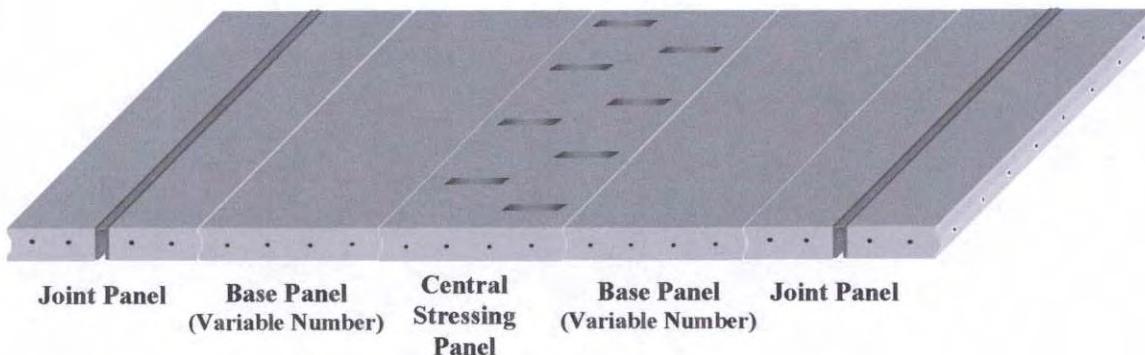
Status / Results: The alternate testing equipment is currently being obtained. Lab testing will be conducted in the summer of 2003 to compare moisture contents between compacted Proctor samples and a TDR device. Later that year, field testing will be conducted using a DCP and moisture content gauge.

RI 03-007 Precast Concrete Panels in New Highway Construction (UMC)

Purpose: The purpose of this investigation is to evaluate the level of installation difficulty and subsequent performance of a PCC pavement composed of precast panels that are post-tensioned after placement. This design is extremely innovative and has been constructed at only one other location in the country thus far. The design minimizes tensile stresses in PCC pavement that lead to fatigue failure. Structurally, an eight-inch precast post-tensioned pavement is equivalent to approximately 14 inches of jointed plain concrete pavement.

Savings / Benefits: This design type, which is still very much in its infancy, may result in significant cost savings at project locations where excessive profile grade changes are not possible (i.e. insufficient bridge clearance) or impact roadside appurtenances (i.e. having to raise guardrail), or where high traffic makes long term lane closures prohibitive.

Status / Results: It is currently anticipated that close to a quarter-mile of this pavement will be constructed on I-57 in Mississippi County, hopefully within FY 2004. The FHWA, which will provide part of the funding for this project, must still select a technical consultant to aid in the design and construction process. The University of Missouri-Columbia will install gauges in the pavement and monitor performance for at least a two-year period.



RI 93-007 Concrete Maturity Test Method

Purpose: The maturity method is a non-destructive means of estimating in-place concrete strength. It is routinely used to facilitate construction operations by allowing timely decisions for removing form work, sawing pavement joints, opening pavement to traffic, and others. Based on the effects time and temperature have on strength gain in concrete, maturity technology provides a reliable method of estimating in-place compressive strength and, thus, avoiding or minimizing the need to fabricate and test conventional cylinders. This study has been an ongoing effort by research staff to investigate the effectiveness of the maturity method for MoDOT application. Several independent projects applying the maturity method have included conventional concrete pavement repair, fast-track ultra-thin whitetopping overlays, and early formwork removal on a bridge substructure.



Savings / Benefits: Proper application of the maturity method can facilitate construction operations saving time and effort. More timely actions can be taken to remove formwork, saw pavement joints, open pavement to traffic, and make valuable decisions during hot-weather and cold-weather concreting.

Status / Results: Research on this study has recently been concluded. It has been found that when proper procedures are followed, reliable estimates of in-place concrete strength can be successfully determined saving considerable time and effort on construction projects.

Implementation: A specification, Strength of Concrete Using the Maturity Method, for application of the maturity method by MoDOT has been developed and is currently available for use on various MoDOT projects.

RI 99-022 New PCC Pavement Design Study (System Preservation)

Purpose: The purpose of this project is to evaluate the effectiveness of the new PCC pavement design. The new PCC pavement design was first initiated in 1993. It utilizes unreinforced concrete, 15' joint spacing with dowel bars, 14' wide paving in the driving lane, tied shoulders, and greater slab thickness. The old design utilized reinforced concrete, 61.5' joint spacing, 12' wide paving in the driving lane, and no tied shoulders.



Savings / Benefits: Elimination of early distresses found in the older pavement design will increase the expected design life of the new PCC design.

Status / Results: An initial survey including falling weight deflectometer (FWD) testing, joint fault measurements, pavement distress examinations, and outlet drain checks were performed on new design PCC pavements across the State in 2000. The overall conditions were excellent. Another survey, minus the FWD testing, will be performed in the summer of 2003.

Mobile Testing Lab Created Out of Necessity

Article originally published in September 2003 issue of *Inside MoDOT*

By Matt Hiebert

Necessity is the mother of invention. The adage may be old, but the idea is alive and well at MoDOT.

Last year, two members of Research, Development and Technology, David Amos, intermediate research and development assistant, and Scott Breeding, intermediate research and development technician, began testing a new concrete evaluation process called the Maturity Method. This process allows the strength of concrete to be measured before it's fully cured.

"As cement hydrates it generates heat," Amos explains. "We can record the temperature and elapsed time of hydrating concrete and accurately estimate its strength in a matter of hours."

While testing the method, the two realized a lot of time was being spent shuttling concrete samples between work sites and the lab.

"We were testing small concrete cylinders every two hours as they cured," Amos says. "So we were spending a lot of time driving back and forth from the work site to the testing lab."

Transporting the cylinders without damaging them was also a concern. They had to arrive intact for accurate testing. To solve both of these transportation problems, the members of RDT came up with a solution: A mobile testing lab.

"We had a 16-foot enclosed trailer that we used to haul all of our signs, sandbags and cones that weren't being used," Amos said. "So we made some modifications and converted it into a mobile lab."

Rotten wooden floors were replaced with aluminum deck plates, electrical wiring was added and storage areas were built. A computer, printer and testing equipment also were added.

"We have some much dust on the job site that we built a Plexiglas case to hold the sensitive equipment and keep it clean," Amos said.



The effect is a strange mixture of high tech and low tech. A laptop computer sits a few feet from a cluster of shovels. A metal ramp built from old sign planks angles up the back of the trailer. A heavy-duty compression strength-testing machine sits on top of a no-frills plywood cabinet.

In the end, tests of the Maturity Method proved the process to be accurate, but that wasn't the only benefit that came out of the experiment.

Not only could they now measure the strength of a concrete sample while it was still curing, but they also had a multifunctional testing lab with the potential to save the department, contractors and taxpayers a lot of time, money and effort.

Safety / Traffic

- Evaluation of Waterborne Traffic Paint and Bead Combination
- Investigation on Centerline Rumble Strips
- Remote Control Flagman
- Edgeline Rumble Strip Configuration
- Design, Fabrication, and Testing of Low-Profile Composite Bypass Road Panel: Phase I

PD 01-021 Evaluation of Waterborne Traffic Paint and Bead Combination

Purpose: The objective of the investigation is to test different combinations of waterborne paint types, thickness, and bead sizes to determine the most effective waterborne pavement marking combination for MoDOT. From the information obtained, MoDOT will try to determine the service life of the material and provide a life-cycle cost of the different materials tested.

Savings / Benefits: Because of heavy volumes of traffic and snowplowing on MoDOT pavements, the investigation should provide the best combination of materials for a particular pavement. By comparing benefit / costs of the different paints / beads, we will select the most beneficial paint / beads, which should allow us to stripe more efficiently.

Status / Results: MoDOT forces will install the three (3) test locations for the waterborne paint in the summer of 2003. A test location will be eight miles long with eight combinations of materials located on old and new asphalt pavement and old concrete pavement separately. The waterborne paint, within the test section, will be studied with both longline (centerline and edgeline) and transverse line as shown in the picture below. Retroreflectivity readings and visual ratings will be performed initially and at approximately 6-month intervals until the pavement material average retroreflectivity readings drop below values of 150 mc/m²/lux for the white paint and 100 mc/m²/lux for the yellow paint. The readings will be read with a LaserLux retroreflectometer.



PD 01-027 Investigation on Centerline Rumble Strips

Purpose: Centerline rumble strips (CRS) have been tested in several states, in an effort to reduce the number and severity of head-on accidents and opposite direction sideswipe accidents on high-speed, two-lane highways. MoDOT is constantly looking for new ways to improve the safety of state highways. If centerline rumble strips prove to be an effective means to increase safety, it will become a desired feature for many of the narrow, winding, two-lane Missouri highways.

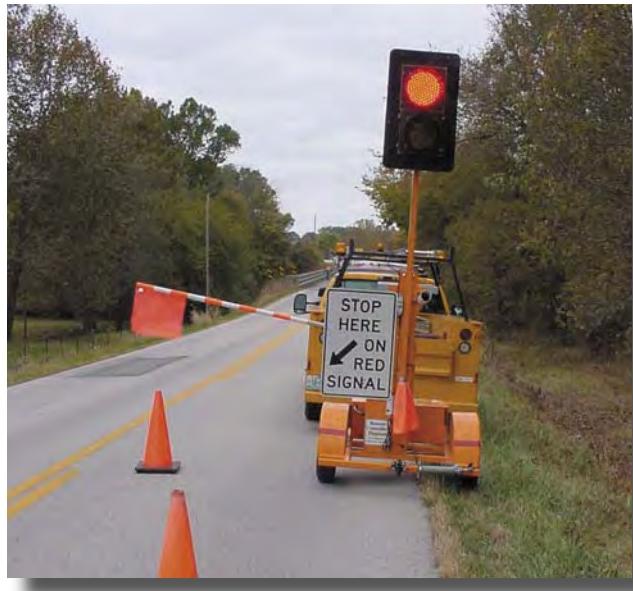
Savings / Benefits: The CRS should increase safety, through the reduction of the number and severity of head-on accidents and opposite direction sideswipe accidents. Any savings would come from less accidents and property damage of motorists.

Status / Results: The CRS will be installed on Route 21, south of St. Louis, in the summer of 2003, and the evaluation will last 5 years after the installation. An interim report will be prepared in the summer of 2005, 2 years after the installation. A final report will be prepared in the summer of 2008.

PD 02-016 Remote Control Flagman

Purpose: The objective of the evaluation is to determine if the Remote Control (RC) Flagman unit will increase work zone safety, improve productivity, and reduce costs. As shown in the picture, RC Flagman is a mechanical flagger that has a red and amber indication signal head attached to a portable trailer with a PVC flagger arm attached to the trailer. The RC Flagman is placed at one end of the work zone as a replacement for one human flagger. On the other end of the work zone, a human flagger controls the RC Flagman with a remote controlled radio.

Savings / Benefits: The anticipated benefits of using the RC Flagman are increased safety, reduced costs, and increased productivity. The safety aspect of the use of one human flagger and a mechanical flagger will reduce worker exposure in the work zone. The RC Flagman's red and amber lights, the larger target area of the signal head, trailer and flagger arm should attract the traveling public's attention of the stop conditions in the work zone. When the RC Flagman can be used, the work force should be able to free a worker to perform work on a project, which may speed the completion of the project and save money.



Status / Results: The RC Flagman units are being used on two-way, two-lane roadways with low average daily traffic (ADT), particularly bridge maintenance projects. An interim report was written in May 2003, and the final report will be prepared by January 2004.

RI 01-057 Edgeline Rumble Strip Configuration (UMR)

Purpose: The objective of this multi-phase project was to develop a set of guidelines for the use and design of shoulder rumble strips in Missouri that address the needs of both motorists and bicyclists. Two questions were asked: First, can shoulder rumble strips be narrowed from the current 36" width and be moved closer to the lane edge line to encourage bicyclists to ride on the right side of the strip? Second, for concrete pavements, can rumble strips be placed between the 12' lane stripe and the 14' edge of pavement without causing damage to the construction joint at 14'?

Savings / Benefits: Shoulder strips are already being implemented in Missouri. Shoulder rumble strips have saved money by decreasing fatalities, injuries, and property damage. It has been shown that rumble strips can reduce run off the road crashes by at least 20%. The implementation of this study may or may not save any additional money but hopefully will advise the motorist sooner when they are leaving the pavement and allow the bicyclist to ride further from traffic. Only a comparison of run off the road crashes prior to and after implementation of the reports recommendation will show if there is an additional savings.

Status / Results: The report is complete and approved for implementation. Edge line rumble strips will be grooved only, located closer to the edge stripe, and less in width.

Implementation: Standard drawings, design standards, and specifications are being revised to show the new rumble strip design.

RI 02-016 Design, Fabrication, and Testing of Low-Profile Composite Bypass Road Panel: Phase I (UMR)



Purpose: Currently, MoDOT constructs a temporary by-pass or roadway around a construction site to maintain traffic flow. The by-pass, or roadway, is normally constructed of asphaltic concrete or Portland cement concrete pavement. When the project is completed, the contractor will tear out the temporary by-pass and will not be able to use the material again in another project. The research investigation will study the feasibility of fiber-reinforced polymer (FRP) systems for low profile by-pass road panels. The ultimate goal would have the FRP panels be a reusable product from one project to another. The proposed panel will be comprised of a sandwich core composite material containing fiberglass skins and an innovative fiber reinforced core material. A low cost vacuum molding process will be used to rapidly infuse the resin throughout the fiber-reinforced polymer panels as shown.

Savings / Benefits: The initial cost would be higher than asphalt or concrete, but with the reusability of the FRP panels the life cycle cost of the panels may be reduced.

Status / Results: The University of Missouri-Rolla is scheduled to complete Phase I of the project by December 2003, which consists of the following: (1) literature search, (2) fabrication and mechanical characterization of FRP panels that have been identified as suitable for this application, and (3) development of schematic solutions for site implementation. If deemed necessary, Phase II could consist of detailed technical specifications and possible field application.



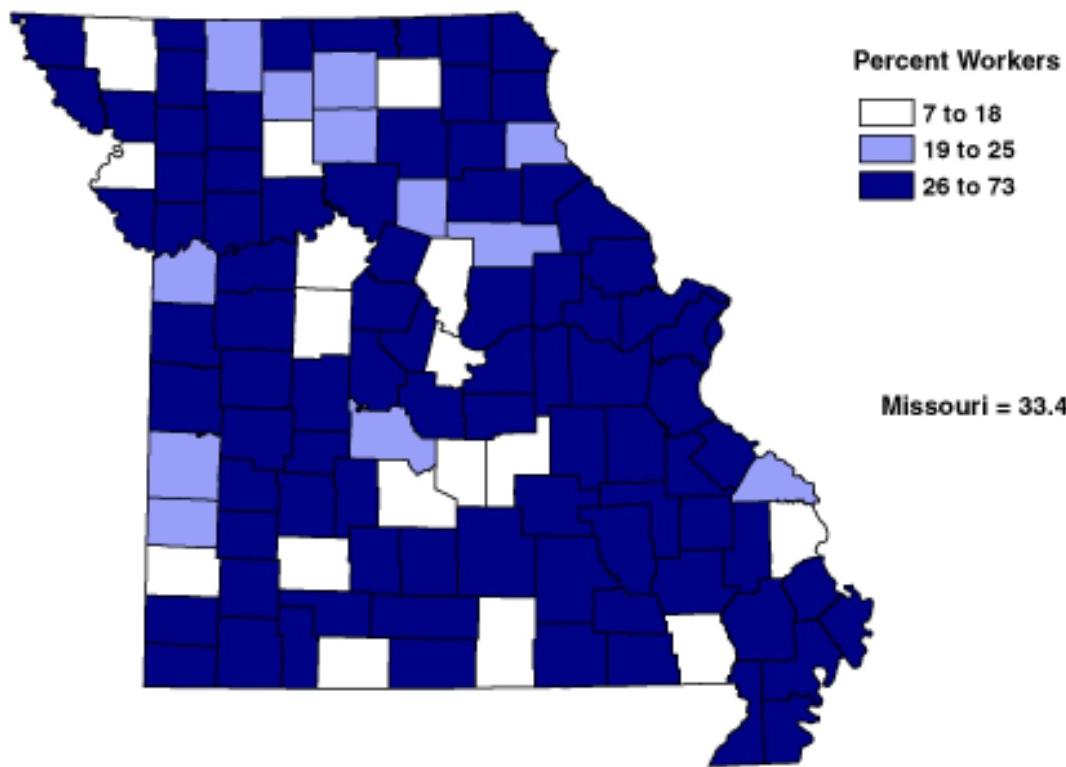
Social Economic Environmental

- Development and Use of Social and Economic Data at MoDOT
- Benefits of Highway Improvements on Rural Communities in Missouri
- Development of Environmental Roadside Inventory Using Spatially Oriented Databases
- Identification and Development of User Requirements to Support Robust Corridor Investment Models
- Ensuring Consideration of Environmental Justice in Transportation Planning and Project Development
- Ownership Review of Missouri's Public Road System
- Development of Improved Road User Cost Program
- MoDOT Customer Survey 2003
- Facilitation of Safety Evaluations of Nighttime and Daytime Work Zones

RI 00-049 Development and Use of Social and Economic Data at MoDOT (UMC)

Purpose: The detailed demographic, social and economic characteristics of Missouri are essential elements of MoDOT planning, project development, and environmental justice functions. This project was designed to customize the 2000 Census data that includes commonly used social, economic and demographic factors into an easy-to-use, authoritative and relevant data source. The information is organized based on the various planning and project development geographies MoDOT employees need to use in their work.

Workers Commuting Outside County of Residence 2000



Source: USDC, Bureau of the Census, Census of Population and Housing [2000 SF3]

Prepared by: University Outreach and Extension, Office of Social and Economic Data Analysis - (OSEDA)

Map Generated on 8.26.2002

The Office of Social and Economic Data Analysis (OSEDA) at the University of Missouri worked closely with MoDOT staff from around the state to develop the web-based Social and Economic Indicator Resource (SEIR).

Savings / Benefits: Besides the time saved by users of the data in having the information already organized for transportation related work, the SEIR helps MoDOT improve the quality of our work through providing the most accurate human dimensions data at the click of the mouse. Neighborhoods, communities, regions, and the state all benefit through the consideration of these social, economic, and demographic factors as we improve the State's transportation system.

Status / Results: The SEIR has been implemented by work units throughout the department and is also used frequently by our transportation partners such as Metropolitan Planning Organizations (MPO's), Regional Planning Commissions (RPO's), as well as other state agencies.

In order to share the SEIR with other users, the project has been presented at numerous planning conferences, the annual TRB meeting, and has been shared with the FHWA Community Impact Assessment working group.

RI00-058 Benefits of Highway Improvements on Rural Communities in Missouri (UMC)

Purpose: It is presumed that economic development benefits are generated for rural counties when highway improvements are made. The purpose of this project is to examine the relationship between the presence of four-lane or two-lane highways in rural counties and their corresponding level of economic development.

Savings / Benefits: Understanding the relationship between transportation improvements and economic development in rural counties can provide information that guides transportation investments to bolster the state's economy. MoDOT can then understand which types of transportation projects provide the greatest benefit to rural areas in the State of Missouri.

Status / Results: To date, a statewide database has been created that contains seven measures of economic development along with the status of counties based on the mileage of four-lane highways in the county. A preliminary analysis of the data indicates that rural counties with four-lane roads demonstrate a small, but significant and positive difference in economic development as compared to counties with only two-lane roadways.

RI01-007 Development of Environmental Roadside Inventory Using Spatially Oriented Databases

Purpose: This project is designed to develop data collection and mapping tools that allow for the effective planning and management of vegetation, mowing, herbicide use and environmental planning of MoDOT right of way. Global Positioning Systems and Geographical Information Systems are being utilized to provide information to roadside managers and environmental specialists. Better data on the roadside environment will aid in effective reduction of mowing, and herbicide use, and will allow labor forces to be redirected to other tasks. When highways are expanded additional benefits will accrue through the environmental clearance and mitigation phases of project development.

Savings / Benefits: The major savings of this project come from a reduction in labor and material costs, both in roadside management and maintenance, and also in streamlining environmental clearances and mitigation. This work has been well received at MoDOT's statewide roadside managers meetings as well as by national leaders in prairie management.



Status / Results: The project is currently expanding to incorporate the inventory and management of other roadway features such as small culverts, guardrail, signs etc. Native prairie and noxious weed locations are being remapped and changes are being studied. The vegetation inventory collected to date is being linked to automated, truck mounted herbicide sprayers. Using the spatial and species data, herbicide is being applied in a more cost effective and environmentally conscious manner.

RI01-011 Identification and Development of User Requirements to Support Robust Corridor Investment Models (UMC)

Purpose: MoDOT is frequently in need of information regarding the economic benefits of particular projects as well as the benefits from our overall program expenditures. The purpose of this project was to identify the best commercially available economic model for MoDOT's use as we examine the benefits of all forms of transportation improvements. As part of the selection of the model, the UMC research team examined MoDOT's decision-making process in order to understand how various factors such as economic development, environmental concerns, and transportation needs could be accommodated by economic models.

Savings / Benefits: As there has not been any consistency in the economic models used to date, the main benefit of this project is in standardizing MoDOT's modeling of economic development benefits. The use of a single model on all projects allows for greater levels of comparison of projects and their benefits, and provides for a consistent reporting scheme. Additionally, the selection of the IMPLAN model allows MoDOT to use the data sources it already has, or can easily acquire. This benefit alone could save over \$100,000 per year in data acquisition costs.

Status / Results: As a result of the project, the IMPLAN economic model has been recommended as the best fit to examine the benefits of MoDOT's programs and policies considering the data and needs considered in the transportation development process. The final report is expected in August of 2003.

RI02-012 Ensuring Consideration of Environmental Justice in Transportation Planning and Project Development

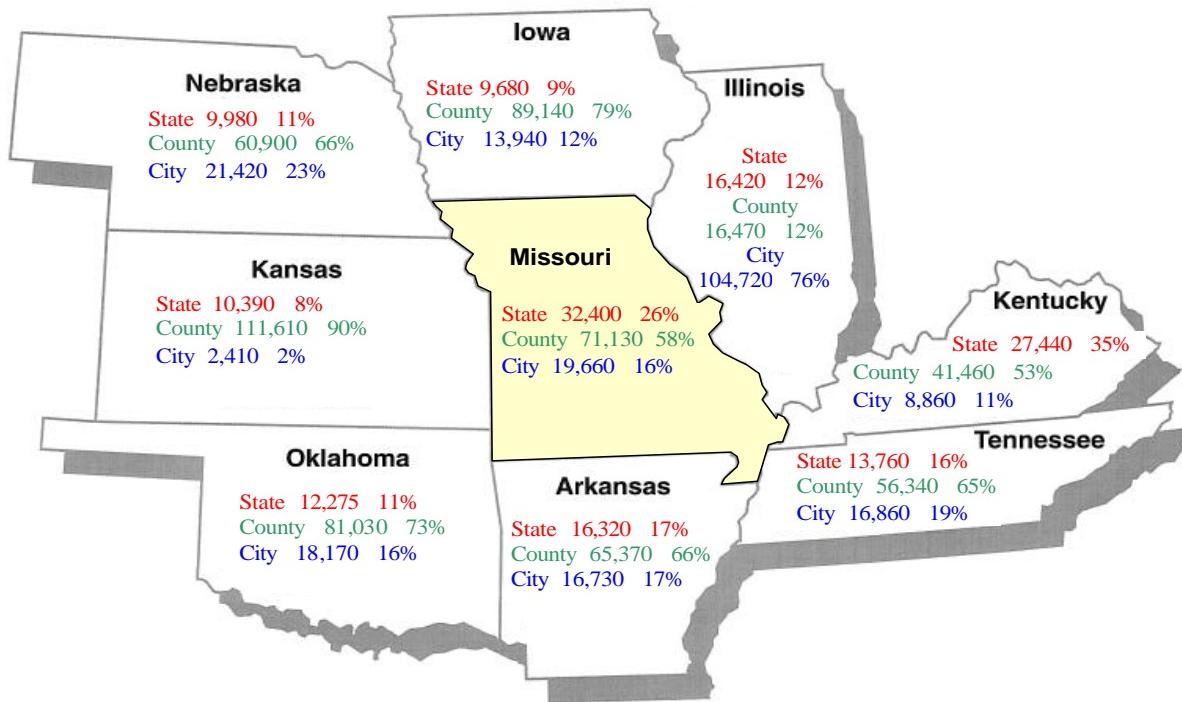
Purpose: In practice, environmental justice involves ensuring that minority and low-income populations do not bear disproportionate, adverse impacts from transportation policies, programs, and projects. The purpose of this project is to identify the work processes within MoDOT that fall under the guidelines provided by environmental justice and Title VI of the Civil Rights Act. The project will then provide practitioners with easy to understand guidelines to ensure MoDOT fulfills the spirit and intent of these important regulatory influences.

Savings / Benefits: Most importantly, this project will provide easy to use guidelines to ensure environmental justice and Title VI are reflected in the State's transportation system. As transportation is now as much a policy and people issue as an engineering function, it is imperative that the human dimensions of transportation are considered.

Status / Results: To date the project has involved a review of all transportation work processes that fall under the guidance provided by environmental justice. Case studies have been established that provide examples of best practices to ensure compliance with the spirit and intent of environmental justice. A final report is expected in January 2004.

RI02-053 Ownership Review of Missouri's Public Road System

Purpose: The Missouri Department of Transportation is currently accountable for over 32,000 miles of public roads in the state. This is more than twice the 14,500 average miles owned by neighboring states. Growing maintenance and expansion needs have made it necessary to review how Missouri's public roads function and how they can be most efficiently maintained.



The State is responsible for crucial highway networks, such as the interstates and arterials. These roads provide mobility, linking urban areas and major sites that are important to efficient movement of people and products. But the State is also responsible for over 24,000 miles of collector roads, business routes and recreational access roads that have local importance but serve low volumes and local traffic. Counties and cities may be able to manage and maintain these roads more efficiently at a level more appropriate to their function. On the other hand, some city owned streets function as major arterials, contributing to overall state mobility, and might be better managed by the State.

Savings / Benefits: Matching the ownership of a road to the way that it functions allows a more desirable level of oversight for maintenance and safety. Local roads are not held to the same requirements as state owned roads and savings might be expected in not trying to meet unnecessary standards. The addition of crucial highways to the state system will help assure a robust transportation system.

Status / Results: The concept of public road review is being presented to county and city officials in an attempt to determine how to meet the needs of the State as a whole. Ownership changes and financial considerations will be discussed as the review proceeds. Any changes will come through a collaborative effort with a vision towards the future.

RI03-019 Development of Improved Road User Cost Program

Purpose: “Road user costs” are the theoretical value of drivers’ time, and sometimes safety and environmental costs, when they are delayed in traffic. They are used as a measure of the societal costs of congestion and work zones. The approach currently used to predict these indirect costs accounts only for the time delay caused by lower speed limits or longer paths. Many programs are available that include the effects of congestion and may aid designers in weighing alternative plans. The purpose of this project is to review current practice and develop a system that benefits MoDOT by tying directly to the road specific data currently available in the Transportation Management System.

Savings / Benefits: A more realistic road user cost will allow MoDOT to better plan work zones and construction projects. Innovative bidding and contracting will help save the department money, while at the same time, reducing the impact of delay on the traveling public.

Status / Results: This project is in the beginning stages of team development and gathering background material. Software programs from the Federal Highway Department and the Asphalt Paving Alliance are being reviewed. This program may tie very closely to the pavement selection process and the life-cycle cost evaluations taking place concurrently.

RI97-034C MoDOT Customer Survey 2003 (UMC)

Purpose: Understanding the perceptions of the State’s residents regarding the transportation system and MoDOT’s performance is an important part of ensuring that MoDOT provides the services and facilities valued by the citizens. The purpose of the Customer Survey 2003 is to measure the perceptions of the State’s residents and compare these perceptions to those collected in the first statewide customer survey conducted in 1999.

Savings / Benefits: Most importantly, the Customer Survey 2003 provides a mechanism to measure MoDOT’s performance as perceived by the state’s residents. This effort provides a grounded and continuous measure of customer satisfaction with the State transportation system and MoDOT’s performance. Only by knowing our customers can we provide services and facilities they value most.

Status / Results: Telephone surveys have been conducted with over 4,000 residents of the state. A report is expected in the fall of 2003 that documents the perceptions, compares these perceptions to the baseline data collected in 1999, and then provides information to MoDOT districts regarding their constituent’s perceptions of local services and facilities.



NCHRP 17-30 Facilitation of Safety Evaluations of Nighttime and Daytime Work Zones

Purpose: With an ever-increasing volume of traffic on the State's roads, it is common practice to conduct road maintenance and construction activities at night to avoid peak traffic volumes and resulting traffic congestion. However, many professionals in the field assume that nighttime work is more dangerous than daytime work for a variety of reasons. The purpose of this project is to examine the hypothesis that nighttime work zones are more dangerous, then to identify and share best practices that can make this inherently dangerous work safer.

Savings / Benefits: If nighttime work zones are indeed more dangerous than daytime work zones, transportation officials must be made aware of the circumstances and appropriate changes should be made immediately. The possible savings in human lives, accident costs, and work efficiency are enormous, and will be measured as part of this important project.

Status / Results: This research idea has been selected as a National Cooperative Highway Research project under the Transportation Research Board. A National panel of experts, including MoDOT personnel, has been selected and will meet beginning the summer of 2003. The panel will further define the project at the national level and oversee the project as it develops.



Photo By: Gerard Kennedy, Nova Scotia Dept. of Transportation

Technology Transfer

- Library Automation Project
- Deployment
- RDT Training
- Technology Transfer Assistance Program (TTAP)
- Publications
- New Center for Transportation Technology Transfer to Missouri Municipalities is Established at UMR
- Summer Transportation Institute

RI 98-026 Library Automation Project (UMC - School of Information Sciences)

Purpose: The purpose of the project is to increase the operation and efficiency of the department's technical library. RDT is in the 2nd year of the project to automate the inventory of its holdings. To date over 2,100 publications have been catalogued.

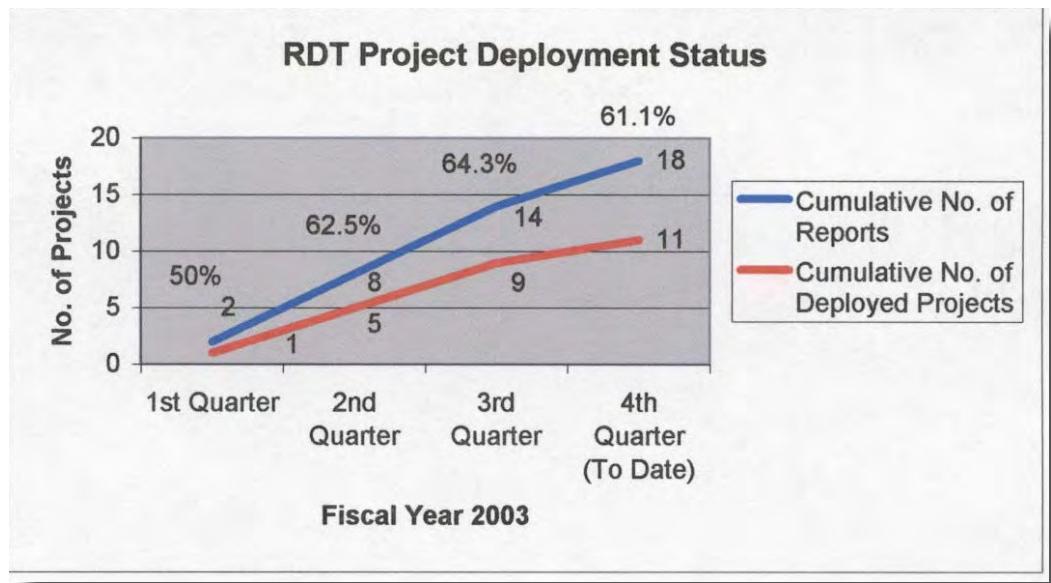
Savings / Benefits: Savings are achieved through improved literature search capabilities for MoDOT staff and on-line customer base. An automated library will serve as an essential tool for literature searches, research analyses, and technology transfer.

Status / Results: The key features of the 1st year of the project include the following: (1) UMC graduate students teamed with members of media conversion to catalogue over 2,100 publications of RDT documents. (2) Guidelines were created in HTML form to help the catalogers locate resource material online, including full Machine Readable Cataloging (MARC) records, and links to Online Computer Library Cataloguing (OCLC). (3) The physical organization of RDT publications was updated by providing shelving tags, check in / out boxes for a self serve library operation. (4) A presentation and a hands-on session was held in April for RDT staff and management. Patrons were given hands-on practice in using the circulation module, and procedures for library use were reviewed. (5) Website development of a "Library Portal" is also underway to allow on-line usage of RDT's library.



Deployment

MoDOT recently enacted the Dashboard / Score Card system of tracking the department's progress in reaching the mission and goals of its business plan. RDT is charged with the task of measuring the deployment of its research results. Over fiscal year 2003, RDT deployed a cumulative percentage of 61.1% of all research projects undertaken.



RDT Training

Purpose: Technical training courses are available to provide direction and support to personnel. These courses are scheduled to maintain an understanding of new needs and enhance abilities to support the core mission of the department. Typical audiences include personnel from FHWA, MoDOT, consultants, and local government. Training is further accomplished by field assistance demonstrations, which depict a hands-on, best practices method of sharing.

Status / Results: Training is an ongoing, annual effort.

TRAINING COURSES SPONSORED BY RDT

FISCAL YEAR 2003

	Consultant	Technical Contact	Date	Location
Drilled Shafts	NHI	Boyd Denson	July 16-19, 2002	Jefferson City
Fracture Critical Inspection Techniques for Steel Bridges	NHI	Carlis Callahan	August 13-16, 2002 August 19-22, 2002	Jefferson City Jefferson City
Safety Inspection of In-Service Bridges	NHI	Mikes Harms	September 11 - October 30, 2002	Jefferson City
Driven Pile Inspection	NHI	Boyd Denson	December 10-13,2002	Jefferson City
Real Estate Appraisal Workshop	NHI	Selene Fults	February 3-6, 2003	Jefferson City
Drilled Shaft Foundation Inspectors	NHI	Mike Fritz	February 19-20, 2003	Jefferson City
Bridge Maintenance Training	NHI	Ken Foster	March 31- April 4, 2003	Jefferson City
Managing Traffic Incidents and Roadway Emergencies	NHI	Mike Stephenson	April 9-10, 2003	Jefferson City
Preventive Maintenance Course	NHI	Tom Anna	April 8-9, 2003 April 16-17, 2003	St. Louis Lee's Summit
Soils and Foundations Workshop	NHI	Kevin McLain	May12-13, 2003	Jefferson City
Culvert Design	NHI	Brian Haeffner	May 14, 2003	Jefferson City

Technology Transfer Assistance Program (TTAP)

Purpose: Technology transfer links MoDOT's research efforts to our transportation partners. The success of a research program is measured in deployment of research results. A critical component in deployment results includes technology transfer. T squared strategies focus on the practical application of research that improves quality, delivery, and the return on investment for our customers.

Savings / Benefits: Savings are accomplished through the implementation of research that meet required functions at a lower life cycle cost to the department. Society savings are also measured in terms of time, safety, and convenience of the traveling public

Status / Results: This is an annual program.

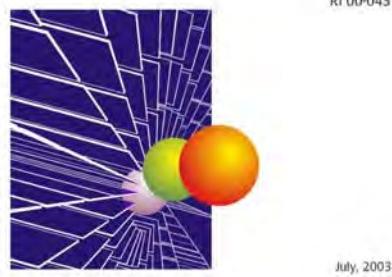
Publications

RDT publishes findings of its research through letters of findings, technical briefs and final reports. Final reports are prepared for all investigations. Reports normally document the work carried out, conclusions reached, and recommendations derived from the investigation. Technical briefs are prepared for most investigations. Technical briefs are detailed documents that summarize complex issues and explain how to implement various technologies or product features. Technical briefs generally give basic practical information that has been written in response to a demand for information on investigations. Technical briefs are aimed at the non-specialist.

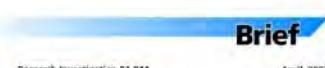
Research Report



Rumble Strips in Missouri



Technical Brief



Laboratory Testing of Bridge Deck Mixes

Project Description
Early crack development has been noticed in many of MoDOT's bridge decks. The cracks have been attributed to high flexural or shrinkage stress development at early ages of concrete. These stresses are believed to be due to the lack of confinement of reinforcing used that shortens the service lives and increases the maintenance costs of bridge decks.

This study was conducted to develop a new bridge deck mix design that has less cracking potential, less permeability, good durability, and adequate strength. The mix designs developed in this study will improve field performance and minimize cracking potential compared to MoDOT's current (B-2) bridge deck mix design.

Laboratory testing on 11 different PCC bridge deck mix designs were conducted. Each test mix differed by the type and/or the amount of supplementary cementitious material that replaced Type I Portland cement. The different mixes are described in Table 1. The aggregate and cementitious materials used in this study included Class C fly ash, ground granulated blast furnace slag (GGBFS), silica fume, and ternary combinations of these materials.

Table 1 - Mix Descriptions

Mix No.	Cementitious Materials
1	Control, 72% B-2, 26% Water Reducer
2	60% B-2, 30% GGBFS, 10% Water Reducer
3	60% B-2, 30% GGBFS, 10% Water Reducer
4	60% B-2, 30% GGBFS, 10% Water Reducer
5	60% B-2, 30% GGBFS, 10% Water Reducer
6	60% B-2, 30% GGBFS, 10% Water Reducer
7	60% B-2, 30% GGBFS, 10% Water Reducer
8	60% B-2, 30% GGBFS, 10% Water Reducer
9	60% B-2, 10% GGBFS & 20% Silica Fume, 10% Water Reducer
10	60% B-2, 10% GGBFS & 20% Silica Fume, 10% Water Reducer
11	60% B-2, 10% GGBFS & 20% Silica Fume, 10% Water Reducer

All publications are posted on the RDT's website at <http://www.modot.org/services/rdt/index.htm>. Each calendar quarter RDT distributes its publications through electronic transmittal to all partners including the MoDOT management, transportation advisory groups, TRB, and national transportation libraries.

New Center for Transportation Technology Transfer to Missouri Municipalities is Established at UMR.

Missouri's Local Technical Assistance Program (LTAP) turned over a new leaf this year. 2002 saw the birth of a new center for transportation education and technology transfer at the University of Missouri-Rolla (UMR): the Missouri Local Transportation Resource Center (MLTRC). Funded by the Missouri Department of Transportation (MoDOT), the Department of Civil, Architectural, and Environmental Engineering, and the University Transportation Center, the center serves as the Missouri branch of the Local Transportation Assistance Program (LTAP). MLTRC, under the direction of Dr. Mohammad Qureshi, provides transportation resources to Missouri's local communities. MLTRC's transportation information is transferred thru the website, mailings and the library. General updates are provided to MLTRC's 3,000 member customer base on a quarterly basis. Training is provided based on customer needs and feedback. MLTRC is advised by a 22 member advisory group comprised of local and state officials around the state of Missouri. An executive working committee of 5 was selected from the full advisory committee to advise on day to day decisions. Over the past year, MLTRC has completed the following deliverables: Through training programs, information resources, and purchasing programs, the center works to get the latest transportation resources out to city and county agencies across the state.



TASK PROGRESS STATISTICS		QUARTER			TOTALS
		2002: 3rd-4th	2003: 1st	2003: 2nd	
New contacts added to the mailing list		2	7	26	35
Mailing list contacts updated		131	26	256	413
Newsletter issues published and mailed		2	1	1	4
Library item requests		1	4	3	8
No. of publication/materials distribution requests		0	10	4	14
Items added to the library		14	17	5	36
Requests for Coop. Program assistance		0	16	34	50
Requests for technical/other assistance (non-Coop)		0	4	10	14
Seminars/training sessions presented		2	6	1	9
Note: at the end of 2nd quarter 2003 there were a total of 3510 individuals on the mailing list					

	Title	Year: Quarter	No. Held	Attendance	
TRAINING DETAILS	Work Zone Safety for Supervisors (2-day workshop)	2002: 3rd-4th	1	16	
	Work Zone Safety	2002: 3rd-4th	1	60	
	Work Zone Safety	2003: 1st	6*	103	
	Work Zone Traffic Control	2003: 2nd	1	10	
	TOTALS	N/A	9	189	
	* 7 sessions were offered, however there was only attendance at 6				

MLTRC takes a two-pronged approach to training. The first prong is the Customized Transportation Education Program (CTEP). Through CTEP the center helps agencies organize learning opportunities tailored to meet their specific needs. The second prong, the Proactive Training Program (PTP), is presently under development and will be initiated this fall. As part of the program, the center will offer a "short course" covering the three most-requested educational topics in each of the 10 MoDOT districts. MLTRC subsidizes the cost of all training offerings to keep the customer cost affordable and practical.



The center's information resources include a quarterly newsletter, lending library, distribution library, and website.

The quarterly newsletter, *MOInfo*, is a joint project with MoDOT's Research, Development, & Technology (RDT) division. The style and format of the newsletter were designed to appeal to a broad audience that ranges from county officials to transportation field engineers. Regular features include the following:

- “New in the Library” — highlights newly acquired library items and materials for distribution;
- “On the Horizon” — details upcoming learning opportunities and conferences across the country; and
- “Tech Brief” — summarizes the latest technical results from RDT transportation research activities in accessible language.

A plan has been put in motion to enhance MLTRC's education and technology transfer capabilities via use of the Internet. Phase I of the plan (fall 2002, spring 2003) included the development of website framework and online forms for requesting training and joining the newsletter mailing list.

The lending and distribution libraries will be published online with search and request capabilities as part of Phase II by the end of summer 2003. Phase III will begin in the fall and includes conversion of library training videos to a "streamable" and downloadable format.

Center operations are guided by Director Mohammad Qureshi, Assistant Professor of Civil Engineering; Program Manager Lonnajean Yoest; and the expertise of an advisory committee which consists of a diverse group of professionals, including MoDOT & Federal Highway Administration personnel, county engineers, and local elected officials. Center activities include substantial involvement of students both at the graduate and undergraduate level, in the hope of spreading interest not only in the transportation field but also in the concept of technology transfer.

Summer Transportation Institute (FHWA, UMR)

MoDOT conducted a presentation for a group of high school students enrolled in the University of Missouri - Rolla's 5th Annual Summer Transportation Institute (STI).

High school students from Missouri, Indiana, Arkansas, Virginia, Mississippi, and Texas took part in a 5 week transportation program at UMR this summer. The purpose of the institute is to introduce the students to careers in transportation and civil engineering. Students enrolled in the program participate in a variety of activities such as: bridge design, construction, mass transit, and communications. Students also develop communication and interpersonal skills through work shops. For the past three years, students have also had the opportunity to take a college level, 3 credit course. The program is funded through the combined efforts of the FHWA, MoDOT, UMR, Burns and McDonnell, Jacob Civil, Parsons Brinckerhoff, and local ITE and ASCE chapters. The program began in 1992 at South Carolina State University. Since 1992, the program has expanded to a total of 42 sites around the United States. UMR was awarded Missouri's program in 1999. Since 1999, UMR faculty have graduated over 91 students. Dr. Gary Spring and Dr. Mohammad Qureshi oversee UMR's STI program.



RESEARCH, DEVELOPMENT AND TECHNOLOGY

Task and Activity
July 2002 - June 2003

<i>TA Number</i>	<i>TA Request Title</i>
TA02-046	New Products Evaluation Programs Maryland State Highway Department
TA02-047	NCHRP Synthesis 33-08, Recruitment and Retention Survey
TA02-048	Information on Organizational Structure
TA02-049	Marketing and Implementation of Research Results (MIRR)
TA02-050	Cost Efficiency Request for MoDOT Management
TA02-051	NCHRP Synthesis Topic 33-04 "Integrated Roadside Vegetation Management"
TA02-052	Nationalrac - Crushed Aggregate Interlayer - Retard Reflective Cracking by WisDOT
TA02-053	Statewide Highway Letting Program Management Questionnaire by Maryland
TA02-054	Salary Survey by Maryland State Highway Administration
TA02-055	Salt Storage Questionnaire by New Mexico DOT
TA02-056	Survey on the Corrosion of Steel Pipe From the Use of Spent Foundry Sand by Indiana DOT
TA02-057 Utah DOT	Survey on Pavement Preservation Seal Coat by
TA02-058	Questionnaire on Quality Control Practices by Iowa DOT
TA02-059	Questionnaire on Testing Water-Borne Traffic Paint by Nevada DOT
TA02-060	Questionnaire on Travel Demand Forecasting for Small Urban Areas by Montana DOT

RESEARCH, DEVELOPMENT AND TECHNOLOGY

Task and Activity
July 2002 - June 2003

<i>TA Number</i>	<i>TA Request Title</i>
TA02-061	Survey on Criminal Background Checks by Maryland State Highway Department
TA02-062	Questionnaire on Cost Overrun Information by Indiana DOT
TA02-063	Evaluation System of Traffic Engineering Measures in Urban Areas by the County of Hungary
TA02-064	Questionnaire on Emerging Technologies in Transportation by Indiana DOT
TA02-065	Estimating Quantities of Water for Dust Control Projects
TA02-066	Questionnaire on Automated Pavement Data Collection Techniques
TA02-067	Questionnaire on Reversible, Express, or HOV Lanes
TA03-001	Questionnaire on the Use of Recessed Reflective Pavement Markers in Snow-Prone Areas from Nevada
TA03-002	Aggregate Sources Survey from North Dakota
TA03-003	Construction Input into Bridge Design Survey from Maine DOT
TA03-004	DOT PCCP Surface Texturing Policy Survey by Utah DOT
TA03-005	Portable Falling Weight Deflectometer
TA03-006	Intermodal Planning Survey by New Mexico DOT
TA03-007	Investigation of the Long Term Effects of Magnesium Chloride and Other Concentrated Salt Solutions on Pavement and Structural Portland Cement Concrete by National Pooled Fund Study

RESEARCH, DEVELOPMENT AND TECHNOLOGY

Task and Activity
July 2002 - June 2003

<i>TA Number</i>	<i>TA Request Title</i>
TA03-008	Overhead Rates for University Research Survey Request by Iowa DOT
TA03-009	NCHRP Problem Statement Process
TA03-010	Estimating the Duration of Highway Construction Projects
TA03-011	Study of Impacts of Speed Limit Changes on High-Speed Roads Survey by NCHRP
TA03-012	Questionnaire for NCHRP Synthesis Topic 34-12, "Access Location on Crossroads in the Vicinity of Interchanges"
TA03-013	Policies on Patents or Copyrights Survey by Iowa DOT
TA03-014	Testing Methods for Abrasion Resistance of Traffic Line Paint Survey by Montana DOT
TA03-015	Questionnaire for NCHRP 34-06 "Convertible Roadways and Lanes"
TA03-016	State DOT Research "Project Selection Process" Survey by Oregon DOT
TA03-017	Safety Considerations for Nighttime / Weekend Construction Activities Survey by South Carolina
TA03-018	NCHRP Synthesis Survey for Study 34-05 on Management of DBE Issues in Construction Contracting
TA03-019	Questionnaire for NCHRP Synthesis Topic 34-07 "Agreements Between Government Entities to Manage Arterial Corridors to Preserve Mobility and Safety"
TA03-020	Survey for NCHRP Synthesis 34-11 "Paving Applications Using Geographic Information Systems"
TA03-021	Compost on Steep Slopes Survey from Montana DOT
TA03-022	Survey on Section 409 Issues by Montana DOT

RESEARCH, DEVELOPMENT AND TECHNOLOGY

Task and Activity
July 2002 - June 2003

<i>TA Number</i>	<i>TA Request Title</i>
TA03-023	Questionnaire for NCHRP Synthesis Topic 34-02 "Road Safety Audits: State of the Practice"
TA03-024	Creative Approaches to an Interchange Design Survey by Maryland State Highway Administration
TA03-025	Longitudinal Edge Drain Detail Survey by Mississippi DOT
TA03-026	Asphalt "Odor Eater" or Smell Additives Survey by Illinois DOT
TA03-027	Rumble Strip Practice and Research Survey by Caltrans
TA03-028	APWA Needs Survey by APWA
TA03-029	Construction Materials Acceptance Survey by Utah DOT
TA03-030	Questionnaire for NCHRP Synthesis Topic 34-10 "Winter Operations"
TA03-031	Deterioration of Longitudinal Paving Joint Survey by Montana DOT
TA03-032	Questionnaire for NCHRP Synthesis Topic 34-01 "Centerline Rumble Strips"

TECHNOLOGY TRANSFER ASSISTANCE PROGRAM

"Final Publications"
July 2002 - June 2003

<i>Title</i>	<i>Research Report Date Published</i>	<i>RDT Brief Date Published</i>
2002 MoDOT RDT Library Peer Exchange	September 2002	
Laboratory and Field Testing of FRP Composite Bridge Decks and FRP Reinforced Concrete Bridge for City of St. James, Phelps County, MO	October 2002	
District 7 Report on Phase 1 and 2 on the Pavement Marking Management System Research Projects	November 2002	
Missouri Guide for Pavement Rehabilitation	November 2002	
Hydrodemolition and Repair of Bridge Decks	December 2002	
Effects of Heavyweight Jackhammer	December 2002	
Flat Free Tire Sealant Study		January 2003
Determination and Prioritization of Geotechnical Problems for Missouri DOT	January 2003	July 2003
Automated Pavement Analysis in Missouri Using Ground Penetrating Radar	February 2003	
Evaluation of Stainless Steel Reinforcement Construction Report	February 2003	
Characterization of Permeability of Pavement Bases in MoDOT's System	February 2003	
Advanced Research of an Image Analysis System for Hardened Concrete: Technical Brief		March 2003
Laboratory Study - Laboratory Testing of Bridge Deck Mixes	March 2003	April 2003
Vertical Shear-Wave Velocity Profiles Generated from the Spectral Analysis of Surface Waves	April 2003	July 2003
Application of Innovative Nondestructive Methods to Geotechnical and Environmental Investigations	April 2003	
Investigation of Dowel Bar Placement Accuracy with a Dowel Bar Inserter	May 2003	

**MISSOURI DEPARTMENT OF TRANSPORTATION
RESEARCH, DEVELOPMENT AND TECHNOLOGY
RESEARCH IDEA STATEMENT**

Research Idea Title:

Research Idea Statement:

Objectives:

For further review, please specify the appropriate Technical Advisory Group (TAG) according to research idea emphasis area.

- Project Development/Bridges
- Operations
- Pavements
- Geotechnical
- Traffic/Safety
- Social/Economic/Environmental
- Other

Implementation of Research Results:

Functional Units Affected:

Name: _____

Date: _____

Title: _____

Functional Unit/Dist. _____

Organization: _____

Phone: _____

Address: _____

Complete and return to:

Missouri Department of Transportation
Research, Development & Technology
P. O. Box 270
Jefferson City, MO 65102
Phone: (573) 751-3002

For RDT Use Only:

RI # _____

TAG Assn _____

ADMIN Approval _____

MISSOURI DEPARTMENT OF TRANSPORTATION

PRODUCT LISTING/NEW PRODUCT EVALUATION REQUEST FORM

When request is submitted, enclose a completed copy of this form and the required information as indicated below.

Circle One: **Manufacturer** **Fabricator** **Distributor** **Other** _____

Business Name: _____ Contact Name: _____

Address: _____ City: _____

State: _____ Zip: _____ Telephone No: _____

Fax No: _____ Email: _____ Website: _____

Product: Name of Manufacturer: _____

Name of Product: _____ Model No. _____

Description and intended application of product: _____

Key words (requested for literature search): _____

List other states using the product: _____

What is the approximate unit cost of the product? _____

Is material available at no cost for lab and field installation evaluation? _____

Applicable Specifications: (MoDOT specifications and MSP's are available at www.modot.state.mo.us/business/business.htm or by request.)

Does product comply with MoDOT specifications? _____ Indicate Yes/No _____ (If yes, provide specification name/number. If no, attach separate explanation as to why not and why MoDOT should consider the product)

Does product comply with other specifications (such as ASTM, ITE, AASHTO, NEMA, NTPEP, etc.)? _____ (If yes, provide specification name and number. Attach additional sheets if necessary.)

Required Information (to be submitted in addition to this form):

- 1) Product data (mixing info, installation requirements, product brochures, specification sheets, etc.)
- 2) Documentation required by the MoDOT specification (if applicable)
- 3) Applicable test data
- 4) Unit cost data and whether the unit cost includes installation
- 5) Material Safety Data Sheet

Submitted by:

(Sign) _____ Date: _____

(Print) _____

Please send the new product evaluation request form and all other required information to the appropriate address below. Submittals related to the Traffic Signal and Highway Lighting Approved Products List should be submitted to Traffic Operations. Submittals that meet a current MoDOT specification and have a Qualified or Pre-Acceptance List should be submitted to Project Operations. All other submittals should be submitted to Research, Development and Technology. If a sample is required by the specification, submit the sample with a copy of the required documentation to the Central Laboratory. If the specification does not specify a sample or there is no specification, sample submittals will be required upon request.

Traffic Operations P.O. Box 270 2211 St. Mary's Blvd Jefferson City, MO 65102	Project Operations P. O. Box 270 2211 St. Mary's Blvd Jefferson City, MO 65102	Research, Development and Technology P.O. Box 270 1617 Missouri Boulevard Jefferson City, MO 65102	Central Laboratory 1617 Missouri Boulevard Jefferson City, MO 65109
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Office Use:

Initial date received: _____ All required documentation submitted? (Y/N) _____

Date of additional documentation receipt: _____ Product Development/NP number assigned: _____

Missouri Department of Transportation
P.O. Box 270
1617 Missouri Blvd.
Jefferson City, MO 65109
www.modot.org

MoDOT Research,
 Development and Technology
 Implementation Form

Ray Purvis, State Research,
 Development and Technology Engineer
 Tim Chojnacki, Director, Research
 Don Davidson, Director, Development
 Michael Shea, Director, Technology
 Transfer

Research Investigation and Implementation

Project Information

Project Title:	Project ID:	Date:
Technical Advisory Group:	Technical Advisory Chair and Phone Number:	
Project Start Date:	Approved Contract Amount:	
Project End Date:	Final Project Expenditures:	
Final Report Draft Date:		
Principal Investigator:	Principal Investigator Phone:	
	E-Mail:	

Technical Advisory Group Recommendation

1. Check one of the two below:
 - Yes. We recommend changes to current practice based on some or all of the results of this report. The research was sound, and the report's conclusions appear to offer an advance over current practices.
 - No. We do not recommend changes to current practice at this time. This approach does not appear fruitful OR future study is needed OR our objectives have changed, etc.
2. If implementation is recommended, we suggest the following specific changes to current practice detailed in the final report and timeline. (check applicable items)
 - Standard Specifications
 - MoDOT Functional Unit Manual (i.e. Maintenance, Design, Construction, Materials, etc.)
 - Standard Drawings
 - Job Special Provisions
 - Training, Outreach
 - Other (describe):
3. Approval of this implementation plan by the Technical Advisory Group (chair on behalf of TAG):

Signature:

Date:
4. Approval of final report and timeline by the MoDOT personnel responsible for the policies described in item # 2 above:

Signature(s):

Date:
5. Approval at Implementation

Name:

Functional Unit:

**Missouri Department of Transportation
P.O. Box 270
1617 Missouri Blvd.
Jefferson City, MO 65109**

MoDOT Research, Development and Technology Implementation Form

Ray Purvis, State Research,
Development and Technology Engineer
Tim Chojnacki, Director, Research
Don Davidson, Director, Development
Michael Shea, Director, Technology
Transfer

Implementation Plan

Project Title

Prepared By:

1. Scope and objectives of implementation, including specific changes to MoDOT procedures:
 2. Estimate cost (if any) to implement.
 3. Expected benefits and how they will be measured (dollar savings, time savings, other).
 4. Possible pitfalls and how they will be avoided.

Research Investigation Number RI 03-043
Report Number RDT 03-014



Missouri Department of Transportation
Research, Development and Technology
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Jefferson City, MO 65102

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